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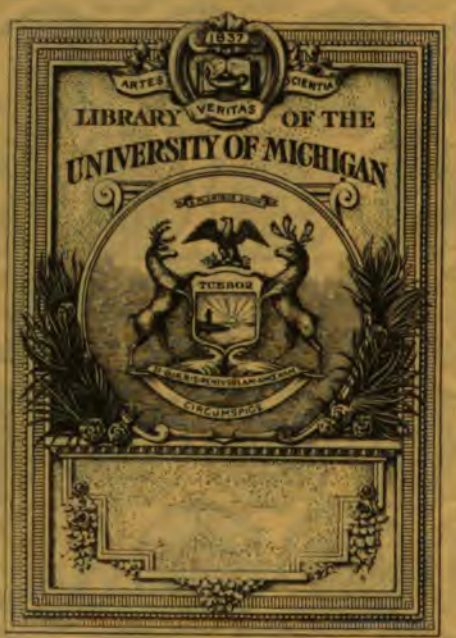
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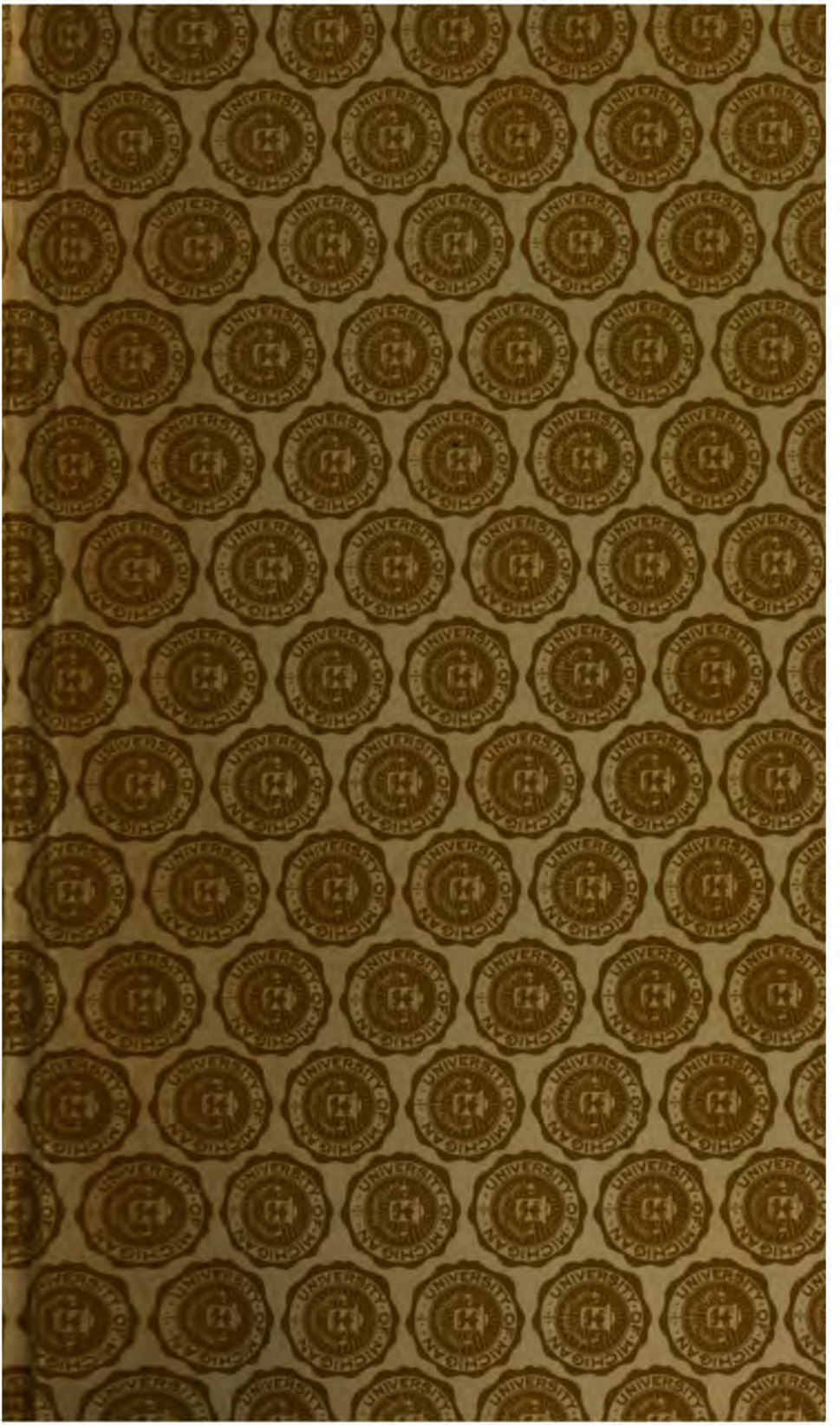

STATE OF TENNESSEE
STATE GEOLOGICAL SURVEY
WILBUR A. NELSON
State Geologist

THE RESOURCES OF TENNESSEE

VOLUMES VII AND VIII

NASHVILLE
1918

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VOLUME VII NUMBER 1

THE RESOURCES OF TENNESSEE

A MAGAZINE DEVOTED TO THE DESCRIPTION, CONSERVATION AND DEVELOPMENT OF THE RESOURCES OF TENNESSEE

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JANUARY, APRIL, JULY AND OCTOBER
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THE RESOURCES OF TENNESSEE

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JANUARY, 1917

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R. S. MADDOX
Forester

C. R. WATKINS, JR.
Traverseman

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Mineral

CORRECTION

In Volume VI, No. 4, p. 194, Table I, change "1914" to "1915".

After the year 1915, in the columns under "Total", let 8,246,030, represent the total number of long tons of phosphate produced in Tennessee from 1894 to 1915, inclusive; and let $28,906,894 represent the value of the phosphate for the period named.

LETTERS OF TRANSMITTAL

NASHVILLE, TENN., December 19, 1916

To His Excellency, the Governor, and Members of the Geological Commission:

GENTLEMEN—In compliance with the law establishing the State Geological Survey, I have the honor to transmit the report of the State Geologist for the biennial term ending December 19, 1916.

Very respectfully,

A. H. PURDUE, *State Geologist*

December 20, 1916

To the Members of the Sixtieth General Assembly of Tennessee:

In accordance with the Act creating the State Geological Survey there is submitted for your investigation the administrative report of the State Geologist, covering the period from December 19, 1914, to December 19, 1916. We bespeak your careful consideration of the report, showing the important field occupied by the Survey and the work done by it during the biennial period that has just closed.

Respectfully submitted,

TOM C. RYE, *Governor, Chairman of the Commission*
BROWN AYRES, *Secretary of the Commission*

Administrative Report of the State Geologist, 1916

SOURCES OF WEALTH

Let it be noticed that the subject of this heading is not wealth, but the *sources* of wealth. Their exact number may be a matter of dispute, but all will agree that two of them are the earth's minerals and the soil. "Minerals" as here used, includes all the material that comes out of the earth which man puts to use. If we ask which is the more important to our welfare, the minerals or the soil, it is like asking which is the more important to life, the lungs or the heart. We could not get along without either. Both the minerals and the soil are essential to life, the industries and progress; and the fullness of our commercial development is measured by the extent to which we utilize these two sources of wealth. The richest centers are those about developed mines, those in well-developed agricultural regions, and those where the products of the mine and the soil are brought together and made into articles of general use.

PURPOSE OF A GEOLOGICAL SURVEY

In general, the purpose of a state geological survey is to investigate and report upon its natural resources. The scope of any particular survey is wide or limited, depending upon the statute under which it is organized. It may include investigations upon minerals, soil, surface features, drainage, forestry, water power, water supply, land reclamation, and so on; or it may be limited to any one or more of these. By the statute under which the State Geological Survey of Tennessee is organized, its scope is so wide as to cover all the purposes named. Whether expressed by statute or not, the duty of aiding in the conservation of a state's resources is always an implied one.

WORK OF A GEOLOGICAL SURVEY

Collecting information.--With the above named duties in mind, it will be seen that the work of a state geological survey is to gather information on the resources of the state it serves, and give this out

to the public. There are two kinds of information: That which comes incidentally from letters to the Survey, from those who call upon it, from newspaper and magazine items, etc.; and that which is secured from the field work of the geological corps. The first source is incidental, though important, and should be compiled for ready reference. The second source is the more important one, and is considered in the following:

Formerly, geological field work was largely of a general nature, and this answered the purpose very well, for its day. But the demands for detailed information have reached the stage that requires such work to be done with all the exactness that is practicable. For example, in the early days, it was sufficient to say that coal occurs throughout most of the Cumberland Plateau area. This very general information does not meet the demands of today. These call for the number of coal beds in the several parts of the region, and the approximate area, thickness, chemical composition, general mining conditions, etc., of each. The geology of these coal beds is so difficult, that much time is required to work it out. The same statement of necessary detail will apply to zinc, copper, marble, phosphate, oil and gas, and other deposits of value, as well as to soil surveys.

This necessity for exactness in geological work calls for correct maps, which for a large portion of the State are not in existence. In such areas, it therefore becomes necessary to make the maps. In this the Survey has adopted the plan of county maps. These maps show all the roads, farm houses, streams, schools, towns, churches, cemeteries, and railroads. It is the intention to make them exact enough for all practical purposes. The scale adopted is uniform for all the maps, and is one mile to the inch. Aside from forming a base for geological and soil mapping, these county maps are sought by farmers, and professional and business men. There are many calls for them, from persons living both in and out of the counties they represent.

The mapping of geological formations as they outcrop at the surface is a work that requires careful training in the science of the subject, and actual practice in the field. In places the work is comparatively easy, and in others it is very difficult, depending largely on the similarity or dissimilarity of the rocks, and the way they lie beneath the surface. Careful mapping of an area requires that the

surface be covered closely, and this requires the geologist to go into the fields, woods and mountains. This makes it necessary for much of the field work to be done on foot, and in some areas all of it must be so done. Geological field work is arduous work.

A map made in this way reliably shows the different formations as they outcrop at the surface and, with the sections accompanying it, how they lie beneath the surface; and the report accompanying the map describes the formations as to their history, character, and economic value.

Giving out information—The information collected by a Geological Survey is given out in printed reports, maps and sections; by correspondence in answer to inquiries by mail; and in interviews with those who come to the office of the Survey for information on the resources of the State. These letters of inquiry and those persons calling at the office for information, come from all parts of the country. No small part of the time of the State Geologist is taken up in attending to them.

POSITIVE AND NEGATIVE INFORMATION

From the economic point of view, the results of geological investigations are both positive and negative. The positive results disclose the location, extent, character and geological occurrence of valuable deposits. The negative results show where deposits of certain kinds can not be expected. As examples of the two kinds of information, we know that oil may occur in some parts of this State, and that it can not occur in other parts; and we have the same information concerning coal, iron, copper, phosphate and other deposits of value. A deposit of one kind may and often does occur in regions where investigation shows there is no possible chance for a deposit of some other kind. Again, deposits of different kinds may and often do occur in the same area.

It is often worth as much to the public to know where a deposit *can not* be found as to know where it *can* be found, for such knowledge would save money. A great deal of money has been wasted in drilling for oil where there was no possibility of securing it, and much money is wasted in prospecting for other material. The Survey is always pleased to save the expense of hopeless search for deposits of any kind, when application for information is made to it.

That is, we are glad to say where certain deposits *can* be found, or where they *may* be found, or where they can *not* be found.

AN UNJUST CRITICISM

Geological surveys are sometimes criticised for appearing on the ground after mineral discoveries have been made, the inference being that after a discovery is made the geologist is useless. This criticism is unjust for several reasons. In the first place, a geological survey has a large area to cover. The area of the State of Tennessee is 42,022 square miles, much of which is mountainous. It is out of the question for the Geological Survey, without unusually large appropriations, to cover the State thoroughly, in even a score of years. To do so would require that every road, ravine, hill and mountain where there is any possible chance of finding valuable deposits be carefully traversed, some of them several times. It can not be expected that a geological survey, especially a young one, can know where all the valuable deposits occur. Again, after a mineral of worth has been discovered, the geologist, by visiting the prospect, can study the nature of the deposit, of the rocks inclosing it, how they outcrop at the surface and how they lie beneath it. From this he can form an opinion as to whether or not prospecting should be continued, how it should be continued, whether or not similar deposits may be expected elsewhere, and if so where they should be sought. And yet again, a valuable deposit may be known to an individual of the community where it occurs, and even to the whole community, and yet the knowledge of it be only local. Usually, those having knowledge of such deposits have neither the means nor experience for their development. It is the duty of a geological survey to bring such to public notice to the end that they may be developed.

There remains the additional fact that both individuals and companies of experience nearly always seek the opinion of the State Geologist before even venturing upon the field investigation of a new mineral find. A state geological survey is the official clearing-house of knowledge concerning its natural wealth. It follows that if every acre of the State had been carefully surveyed for mineral wealth, the office of State Geologist would still be necessary to its interests, for official detailed information concerning this mineral wealth will always be sought. This information can be reliably given

only by a geologist who is well grounded in the principles of the science and who is familiar with the geology of the entire state.

PUBLIC AND PRIVATE INTERESTS

A geological survey is conducted for the good of the state as a whole. To be most efficient, the work must be systematically planned ahead, and the plans faithfully followed. This requires that the members of the survey keep at the investigations assigned each, until they are finished, unless such unusual conditions arise as to justify a change of plans. Ordinarily, the plans of the Survey can not be interferred with to comply with requests for other work. These requests are of three kinds: Those that are certainly of private nature; those that are as certainly of public nature; and those of uncertain nature. The members of the survey could be kept busy going here and there upon requests of large enough importance to be of general public or at least community interest, but if this were done we should have but little of value at the end of the year to show for the money expended.

The Survey is sometimes embarrassed, and causes embarrassment, by having to refuse requests for work that plainly is of private nature. These requests are made in good faith, on the belief that a public office should make all investigations it is asked to make, the persons making them not stopping to distinguish between interests that are public and those that are private.

It will plainly be seen that the State should not bear the expense of reporting on a tract of phosphate or other mineral land, for a private company, except in such cases as the work will fit in with larger work already in hand. Nor should it bear the expense of reporting on land individually owned. Neither should the State bear the cost of expensive private analyses of minerals, rock or water, except where such analyses are needed to complete investigations that are in progress by the Survey. To do so, would require several chemists, constantly employed. It sometimes happens, however, that mineral specimens sent in to the Survey give promise of general value to the State, and in such cases complete analyses are made. Also, there are similar cases in which the Survey should look into, and give its opinion on deposits privately owned. For example, of such nature would be a deposit of zinc, which if successfully devel-

oped by the owners, would give promise of opening up a zinc mining area of greater or less extent.

An exception to the general rule against doing private work is made in the examination of mineral specimens sent to the Survey, post-paid. Such examinations usually require no great amount of time, and consists only in determining the general nature of the mineral. This, with its mineralogical name, the theoretical amount of each element composing it, and the uses to which it is put, are reported to the sender. One or more of such reports are made almost daily.

CONSERVATION

The duty of a state geological survey does not stop with calling attention to material of economic value, but extends to the utilization of material without waste. An idea of what is meant by this will be had from reading the accompanying article in this issue, on "By-product coke oven opportunities in Tennessee".

By statute it becomes the duty of the State Geological Survey to aid in reclaiming waste land. In compliance with this, surveys have been made of certain lowlands in West Tennessee to determine the feasibility of draining them, and for more than two years constant effort has been made toward reclaiming the enormous acreage of gullied land in certain parts of the State. The work of the latter is more fully described under the heading of "Forestry", later in this report.

MINERAL RESOURCES OF TENNESSEE

Perhaps no state in the Union has a greater variety of mineral resources than Tennessee. Of prime importance are barite, bauxite, clay, coal, copper, iron, marble, phosphate, and zinc. Of secondary importance are gold, guano, greensand, lead, manganese, mineral waters, nitrates of caves, and slate. Then there are the more common yet valuable deposits of sand and gravel, building stone, cement material, and road material. Oil and gas are not mentioned in either class because the development of these products has not been extensive enough to determine their importance.

Tennessee has not reached the rank as a mining state that its remarkable mineral resources entitle it to hold, and that there is all reason to expect of it within a few years. Neither are its manufacturing interests, which should go hand in hand with mining, devel-

oped as they should be. With its large amount of motive power in the form of coal and waterpower, and with an abundance and variety of raw material right at hand, Tennessee should soon take high rank as a manufacturing state. This phase of the State's development should have all the encouragement it can get.

GEOLOGICAL WORK OF THE SURVEY

Coal.—The work on the coal field of the Cumberland Plateau is under the immediate supervision of Dr. L. C. Glenn. It has been in progress since 1910, but has been interrupted by the duties of Dr. Glenn as Professor of Geology in Vanderbilt University, and by the retirement from the Survey in September, 1914, of Mr. W. A. Nelson, who was assisting him. Part of the summer of 1915 was spent by Dr. Glenn in the northern part of Cumberland Plateau, and in a reconnaissance trip over the southern half of the Cumberland coal field. A few field trips were made by him during the fall and winter of 1915-16. Most of his time given the Survey in 1916 was employed in the preparation of the report.

In the early part of 1915, under coöperative arrangement with the U. S. Geological Survey, F. R. Clark of that bureau collected 411 samples of coal from the mines in all parts of the Cumberland Plateau, for analysis. The analyses were made in the Bureau of Mines' laboratory, at Pittsburg, Pennsylvania, and as elsewhere stated in this report, were published by the U. S. Geological Survey, Bulletin 621-P, pp. 269-365, 1916.

Gravel.—In the work on mapping the Cretaceous formations in West Tennessee, Mr. Bruce Wade gave special attention to the gravel deposits that occur in the vicinity of Tennessee River. These will have attention later in a paper by Mr. Wade, giving their distribution and discussing their economic importance.

Manganese.—As was true of many other minerals, the European war created a demand for manganese far above the average, and numerous inquiries came as to its occurrence in Tennessee. To add to the information the Survey already had, the State Geologist, in the early part of 1916, visited the deposits that occur in Bradley, Monroe, Sevier, Cocke, Hamblen, Unicoi, and Carter counties. His observations on manganese in these counties, with those of Mr. O. P. Jenkins on that mineral in Johnson County, were published in the *Resources of Tennessee,* Volume VI, No. 2, pp. 106-123.

Marble.—During the past two years, Dr. C. H. Gordon, engaged in marble investigations, spent somewhat more than two months, mainly in the preparation of the report on field work previously done, though a few days were spent in the field. With the exception of the preparation of the maps to accompany his report, it is now ready for publication.

Oil and gas.—During the last two years oil has been eagerly sought in all parts of the country, and Tennessee has had its share of attention. Some oil development was made at Oneida, Scott County, in 1915 and 1916. During the months of July and August, 1915, Mr. H. F. Bain was sent to Oneida, where he spent 32 days in keeping logs of wells as they were being drilled. The purpose of this was to enable the Survey intelligently to study the oil conditions of the Cumberland Plateau as these were made known by the drill. In addition, Dr. L. C. Glenn, at different times made trips to the field during the development. His investigations were published in the *Resources of Tennessee*, Vol. V, No. 4, pp. 174-194. More recently, some wells have been brought in at Glenmary, Scott County. These also have been visited by Dr. Glenn, and an account of them appears in this issue of the *Resources of Tennessee.*

In the *Resources of Tennessee,* Vol. VI, No. 1, January, 1916, pp. 1-36, there are two articles by the State Geologist, one on "Oil and gas conditions in the Central Basin of Tennessee" and one on "Oil and gas conditions of the Reelfoot Lake district of Tennessee".

The possibility of oil and gas in the southern part of Cumberland County is set forth in an article, with map, by Charles Butts, of the U. S. Geological Survey, in the *Resources of Tennessee,* Vol. VI, No. 2, April, 1916, pp. 108-110. As a result, a good deal of land southwest of Crossville has been leased for oil by one of the leading oil companies of the country.

Phosphate.—In the summer of 1914, Mr. J. S. Hook spent about three weeks on the investigation of the white phosphate deposits of Perry and Decatur counties, the entire summer of 1913 having been spent by him in the study of the brown and blue phosphates of south-central Tennessee. A preliminary paper by Mr. Hook on the white phosphates appears in the *Resources of Tennessee,* Vol. V, No. 1, pp. 23-33. He has in preparation a more exhaustive general paper on all the productive phosphate deposits of Middle Tennessee.

In January, 1915, phosphate was discovered in Johnson County, Tennessee. The report of the discovery brought a good many inquiries to the office of the Survey, with the result that Mr. O. P. Jenkins was sent to investigate the deposits, and spent the summer of 1915 at this work. His report is published in the *Resources of Tennessee,* Vol. VI, No. 2, pp. 51-106.

In the *Resources of Tennessee,* Vol. VI, No. 4, pp. 193-216, there is an article by W. C. Phalen of the U. S. Geological Survey on "The conservation of phosphate rock in Tennessee". This paper discusses the general nature of the phosphates of Tennessee, and the methods used in this State of mining phosphate rock and preparing it for the markets.

General Geology.—From May 24th to October 24th, 1915, Mr. Bruce Wade was engaged in the detailed field work necessary to mapping the geological formations in McNairy County. According to the plans of the Survey, this was the beginning of the geological mapping of a belt of country lying mainly west of Tennessee River and extending northward across the State, known in geology as the Cretaceous area of Tennessee. The average width of this belt is perhaps forty miles. In the southern part of the State, it extends across Tennessee River, into Hardin County. From October 24, 1915, to June, 1916, Mr. Wade, while a graduate student in geology at Johns Hopkins University, did an aggregate of two months' work, at such times as his studies would permit, on the McNairy County geological report.

On June 1, 1916, Mr. Wade resumed his field work and continued it until November 1st, at which time the mapping of Cretaceous deposits of Hardeman, McNairy, Hardin and Chester counties had been completed. During the present collegiate year, he, while yet a student at Johns Hopkins, will put in such time as he can on the report of his field work.

From June 28 to September 15, 1915, Dr. J. J. Galloway and Mr. H. N. Coryell were employed in studying the areal, stratigraphic and economic geology of Rutherford County. This was done under coöperative arrangement between this survey and the Agricultural Experiment Station, University of Tennessee. In connection with the geological mapping of this county, a part of the field work was done for a soil map. During the winter of 1915-16, Dr. Galloway prepared the report on this county, which is now ready for publication.

County maps.—During the years 1915-16 Mr. C. R. Watkins has been constantly employed in the traverse and office work necessary to the preparation of county maps. His work has been on McNairy, Hardin, Shelby, Decatur, Henderson, Chester, and Hardeman counties. In 1914 Mr. Watkins was associated for a time with F. W. Farnsworth in the work on McNairy County, and in 1915 was assisted in Hardin County by A. P. Miller. The following tables show the mileage traversed, by counties:

McNairy County (complete)		
Roads and railroad	1232 miles	
Streams	350 miles	
Levels run	82 miles	
Total		1664 miles
Hardin County (incomplete)		
Roads	420 miles	
Streams	170 miles	
Levels run	25 miles	
Total		615 miles
Shelby County (complete)		
Roads and railroads	2170*miles	
Streams	230 miles	
Total		2400 miles
Decatur County (complete)		
Roads	680 miles	
Streams	92 miles	
Total		772 miles
Chester County (complete)		
Roads and railroads	820 miles	
Streams	120 miles	
Total		940 miles
Hardeman County (incomplete)		
Roads	240 miles	
Streams	36 miles	
Total		276 miles

Concluded on p. 15.

*Of this amount, 310 miles were traversed by Mr. R. T. Allen, of the U. S. Bureau of Soils.

Henderson County (incomplete)	
Roads	685 miles
Streams	95 miles
Total	780 miles
Grand Total traversed	7447 miles

In addition to the traverse work done by Mr. Watkins in the counties named, Messrs. G. M. Ferris and F. M. Maloney were employed in the summer of 1915 in traverse work for the map of Rutherford County. The map of this county was partly compiled from maps of the U. S. Geological Survey. No record is at hand of the mileage traversed by the employes of this Survey, but the area mapped by them covered about one-third of the county.

Soil maps.—During the summer and fall of 1915 Mr. R. T. Allen of the U. S. Bureau of Soils was engaged in mapping the types of soil in Shelby County. This was done under a coöperative agreement between the Bureau of Soils and this Survey, by which the latter was to supply the base map and the former do the soil mapping. Mr. Allen was transferred to another area before the work was completed and it was finished in the early part of 1916 by Mr. Hugh H. Bennett, of the Bureau of Soils, by which the report will be published.

In the summer of 1916, Mr. H. N. Coryell completed the soil map of Rutherford County, which, as above stated, was made in coöperation with the Agricultural Experiment Station, University of Tennessee. Mr. Coryell will prepare the report on the soils of this county during the present winter, as he can spare the time to do so from his studies as a graduate student in geology, University of Chicago.

WORK OF THE CHEMIST

The following is the report of Dr. Paul C. Bowers, Chemist of the Geological Survey, of work done from January 1, 1915, to November 25, 1916:

Determination of mineral specimens sent to the Survey.—Reports made, 373; number of specimens reported, 576; number of mineral contents reported in specimens, 1216.

Quantitative analyses.—Partial chemical analyses, 129 samples; complete chemical analyses, 14 samples; number of determinations in partial and complete analyses, 643.

A little more than two months of the summer of 1915 were spent by Dr. Bowers in the laboratory of the Bureau of Mines, at Pittsburgh, Pennsylvania, assisting in the analyses of 411 samples of Tennessee coal.

WORK OF THE FORESTRY DIVISION

During the years 1915 and 1916, the efforts of the Forester, Mr. R. S. Maddox, were exerted along the lines of practical forestry and educational work.

In practical forestry, 19 experiments in reclamation of gullied land were started under the immediate supervision of the Forester, and many others were undertaken upon his suggestion, but not by his personal assistance. Black locust seed were secured for 18 farmers who were willing to plant them for seedlings. What is equally encouraging, 5,000 black locust seedlings were set out on abandoned land in the spring of 1915, more than 50,000 in the spring of 1916, and 16,000 have already been ordered through this office for next spring's setting, independently of those ordered direct by the farmers themselves. Some farmers are using Bermuda grass and honeysuckle vines in addition to black locust, to reclaim waste land. Roots of the kudzu plant, a little known perennial legume, were sent to 30 farmers to try experimentally on waste land.

In the educational line, Mr. Maddox delivered a week's lectures on forestry during the summer session of the Middle Tennessee State Normal School, and during the two years gave between 50 and 60 talks at different places in the State. A forestry exhibit was made at the State fair, and at the Knoxville and Dresden fairs. Numerous gully and fire posters have been put up, and 7 clubs have been organized in West Tennessee, for the reclamation of gullied land.

Forestry in America is new and the conception of its importance is of slow growth, but the results of the past two years' work of the Forester are encouraging, both in what it promises toward the reclamation of waste land and in the general interest in forest conditions.

GEOLOGICAL CORPS

During the years 1915 and 1916, the following named persons were employed, most of them for only a part of the time, on this Survey:

A. H. Purdue, *State Geologist.*
Wilbur A. Nelson, *Assistant Geologist.*
Olaf P. Jenkins, *Assistant Geologist.*
J. A. Switzer, *Hydraulic Engineer.*
Paul C. Bowers, *Chemist.*
R. S. Maddox, *Forester.*
L. C. Glenn, *Temporary Geologist in charge of coal work.*
C. H. Gordon, *Temporary Geologist engaged in marble studies.*
Bruce Wade, *Temporary assistant in areal geology.*
J. J. Galloway, *Temporary assistant in areal geology.*
Reese F. Rogers, *Assistant on brown iron ore.*
C. R. Watkins, Jr., *Traverseman.*
G. M. Ferris, *Traverseman.*
F. W. Farnsworth, *Traverseman.*
A. P. Miller, *Traverseman.*
E. A. Eubank, *Traverseman.*
J. T. Haden, *Draftsman.*
H. F. Bain, *Assistant.*
Elizabeth Cockrill,* *Secretary.*
Lewis M. Childress, *Secretary.*
Hobart Watson, *Laboratory helper.*

COÖPERATIVE EMPLOYES

The following named persons were employed a part of the time in 1915 and 1916, representing organizations that were coöperating with this Survey:

T. Nelson Dale, *representing the U. S. Geological Survey in marble investigations.*
F. R. Clark, *representing the U. S. Geological Survey in collecting coal samples.*

*After more than six years of efficient service as Secretary of the Survey, Miss Cockrill retired at the end of September, 1916, and was succeeded by Miss Lewis M. Childress.

Charles Butts and George H. Ashley, *representing the U. S. Geological Survey in the Crossville coal area.*

W. C. Phalen, *representing the U. S. Geological Survey in phosphate investigations.*

Oliver Bowles, *representing the U. S. Bureau of Mines in marble investigations.*

Hugh H. Bennett and R. T. Allen, *representing the U. S. Bureau of Soils, in the soil survey of Shelby County.*

H. N. Coryell and F. M. Maloney, *representing the Experiment Station, University of Tennessee, in the soil survey of Rutherford County.*

PUBLICATIONS

The following is a list of the publications of the Geological Survey from December, 1914, to December, 1916:

The Resources of Tennessee, Volume V, Nos. 1, 2, 3, 4.

The Resources of Tennessee, Volume VI, Nos. 1, 2, 3, 4.

Bulletin 18—Administrative Report of the State Geologist, published December, 1914.

Tennessee coal analyses, published in Bulletin 621-P, U. S. Geological Survey, pp. 269-365, 1916.

Geological map of Tennessee, published 1915.

Map of Lewis County, published 1915.

Map of Rutherford County, published 1916.

Map of McNairy County, published in 1916.

MANUSCRIPTS AND MAPS

Some of the following manuscripts and maps are ready for publication, and the others are in course of preparation:

The Historic Geology of Tennessee, by O. P. Jenkins.

The Marbles of Tennessee, by C. H. Gordon, T. Nelson Dale and Oliver Bowles (in preparation).

The Geology of Rutherford County (with map), by J. J. Galloway and H. N. Coryell (ready for the press).

Elevations in Tennessee, by Elizabeth Cockrill (ready for the press).

The Tennessee Coal Fields, by L. C. Glenn and Wilbur A. Nelson (in preparation).

Tennessee Phosphate, by J. S. Hook (in preparation).

Geology of the Crossville Area, by Charles Butts (in preparation).

Geology of McNairy County, by Bruce Wade (in preparation).

The Cretaceous Geology of Decatur County, by Bruce Wade (in preparation).

The Cretaceous Geology of Hardin County, by Bruce Wade (in preparation).

Map of Decatur County (ready for the press).

Map of Chester County (ready for the press).

Map of Henderson County (in preparation).

Marketing Woodlot Products in Tennessee, by W. D. Sterrett (ready for the press).

TABLE OF EXPENDITURES FROM DECEMBER 19, 1914, TO DECEMBER 19, 1916

	Office Salary	Field Salary	Field Expenses	Printing and Engraving	Equipment	Supplies	Postage	Freight, Drayage Telep., Etc.	Miscellaneous	Total
ADMINISTRATION:										
General	$ 3,695 94	$ 183 32	$ 227 58	$ 49 25	$ 423 85	$ 39 48	$ 52 00	$137 54	$86 39	$ 4,895 35
SURVEY AND REPORT:										
General	90 00	1,412 96	467 82	13 25	1,015 98	154 21	.....	4 86	.....	3,159 08
LIBRARY	.....	.....	.....	.....	362 80	.....	.....	16 10	.....	378 90
LABORATORY	2,836 50	.....	.....	22 50	4 13	294 05	.....	.....	.....	3,157 18
AREAL GEOLOGY:										
Crossville	.....	.....	18 00	.....	.....	.....	.....	.....	.....	18 00
McNairy County	200 00	634 90	442 37	.....	.....	.....	.....	.....	.....	1,277 27
Rutherford County	125 00	400 00	39 86	.....	.....	.....	.....	3 13	.....	567 99
Hardin County	.....	343 33	224 03	.....	.....	17 11	.....	.....	.....	584 47
Decatur County	.....	166 67	105 81	.....	.....	.....	.....	.....	.....	272 48
Chester County	.....	64 50	51 60	.....	.....	.....	.....	.....	.....	116 10
Hardeman County	.....	22 60	18 00	.....	.....	.....	.....	.....	.....	40 60
METALLIC ORES:										
West Tenn. Iron Ore Region	164 50	15 00	8 35	150 00	.....	.....	.....	.....	.....	337 85
Zinc in East Tennessee	.....	.....	8 70	.....	.....	.....	.....	.....	.....	8 70
FUELS:										
Coal	1,263 95	348 25	559 64	.....	.....	.....	.....	2 25	.....	2,174 09
Oil and Gas, Special	.....	88 00	27 00	.....	.....	0 75	.....	.....	.....	115 75
BUILDING STONE:										
Marble	622 45	40 00	11 92	.....	.....	3 43	4 50	1 02	.....	683 32
CHEMICAL ARTS:										
Phosphate	55 00	.....	.....	.....	.....	.....	.....	.....	.....	55 00
SOIL SURVEY:										
Shelby County	.....	614 32	472 27	.....	.....	.....	.....	.....	.....	1,086 59
FORESTRY:										
General	1,719 91	2,083 27	626 02	63 50	5.75	.....	20 00	.....	.....	4,518 45

INFORMATION:										
General	2,732 42	177 66	101 78	7 00	7 50	271 27	199 00	1 31	.....	3,497 94
Photographs	.....	.....	.....	.....	40 18	4 24	.....	.....	.....	44 42
STATE EXHIBIT	.....	.....	.....	.....	4 75	4 80	.....	.....	.....	9 55
RESOURCES OF TENNESSEE	1,077 64	208 00	55 54	2,184 60	.....	21 62	68 00	0 50	0 50	3,616 40
STATE MAP	125 00	.....	.....	1,496 20	.....	59 25	21 00	7 47	.....	1,708 92
HISTORIC GEOLOGY BULLETIN	616 66	.....	.....	.....	.....	.....	.....	.....	.....	616 66
COUNTY MAPS:										
McNairy County	.....	450 00	408 47	.....	.....	.....	.....	1 01	.....	859 48
Hardin County	.....	276 34	413 08	.....	.....	.....	.....	.....	.....	689 42
Rutherford County	.....	134 00	208 60	124 00	.....	2 23	.....	6 49	.....	475 32
Decatur County	.....	308 75	394 41	.....	.....	0 75	.....	.....	.....	703 91
Chester County	.....	240 00	191 50	0 85	.....	.....	.....	.....	.....	432 35
Henderson County	.....	145 50	131 21	.....	.....	.....	.....	.....	.....	276 71
Hardeman County	.....	57 75	64 57	.....	.....	.....	.....	.....	.....	122 32
ECONOMIC GEOLOGY:										
Johnson County	300 00	565 00	228 68	.....	.....	.....	.....	.....	.....	1,093 68
Total	$15,624 97	$8,980 12	$5,506 81	$4,111 15	$1,864 94	$873 19	$364 50	$181 68	$86 89	$37,594 25

The total amount expended for geological and soil survey work in Tennessee from December 19, 1914, to December 19, 1916, is shown in the following table. With the exception of the first item, this money was expended under coöperative arrangements between this Survey and other organizations:

Table of total expenditures

Expenditures as shown by the preceding Table of Expenditures	$ 37,594 25
Expended by the U. S. Bureau of Soils in the Survey of Shelby County	$ 1,864 46
Expended by the Agricultural Experiment Station, University of Tennessee, in the survey of Rutherford County	1,472 00
Expended by the Bureau of Mines in marble investigation	160 00
Expended by the U. S. Geological Survey in marble investigation	549 72
Expended by the U. S. Geological Survey in collecting samples of Tennessee coal	640 00
Expended by the U. S. Geological Survey in the Crossville coal area	185 63
Total	$ 42,466.06

APPROPRIATION REQUESTED

The following appropriation is requested of the Sixtieth General Assembly and has been approved by the Geological Commission:

For the purpose of carrying on the work of the Survey in accordance with Senate Bill No. 330, Chapter 569, Acts of 1909, from May 1, 1917, to May 1, 1919, salaries and expenses	$30,000
To be applied toward publishing the *Resources of Tennessee*	2,000
To be applied toward the publication of bulletins	6,000
For the maintenance of the Forestry Division of the Survey, salaries and expenses	6,500
Total	$44,500

ACT ESTABLISHING THE GEOLOGICAL SURVEY

The bill establishing the State Geological Survey was passed by the Fifty-sixth General Assembly of Tennessee in 1909, and is as follows:

CHAPTER 569

SENATE BILL No. 330

(By Messrs. Greer, Huffaker, and Neal.)

A BILL to be entitled An Act to establish and create the bureau to be known as the State Geological Survey; defining its objects, powers, and duties; providing for the appointment of a State Geologist, and defining his powers and duties; permitting coöperation with Federal and State bureaus in furthering the objects of this Act; providing for the publication of the results of the survey; providing for the collection of exhibits of the natural resources of the State, and for the final disposition of the equipment and property of the Survey; authorizing entrance upon private lands in the prosecution of the work of the survey; and making the appropriations for the enforcement of this Act.

SECTION 1. *Be it enacted by the General Assembly of the State of Tennessee,* That there be, and is hereby, created and established a bureau to be known as the "State Geological Survey," which shall be under the direction of a Commission to be known as the "State Geological Commission", composed of the Governor (who shall be ex-officio Chairman of said Commission), the State Commissioner of Agriculture, the State Mine Inspector, the President of the University of Tennessee, the Chancellor of Vanderbilt University, and the Vice Chancellor of the University of the South.

SEC. 2. *Be it further enacted,* That the said Commission shall have general charge of the State Geological Survey and shall appoint as Director a Geologist of established reputation, who shall be known as the "State Geologist," and upon his recommendation such associate geologists, assistants, and employees as may be necessary to carry out successfully and speedily the work of the Survey.

The Director, associates, assistants, and employees appointed under the provisions of this Act shall receive such compensation as shall be determined by the Commission. The said Commissioners shall serve without compensation, but shall be reimbursed for actual expenses incurred in the performance of their official duties.

SEC. 3. *Be it further enacted,* That the said Commissioners shall meet for organization within thirty days after the passage of this Act, and shall appoint a Director as soon thereafter as possible. The regular meetings of the Commission shall be held on the first Wednesday in May and the first Wednesday in November of each year in such place as the Commission shall determine.

SEC. 4. *Be it further enacted,* That it shall be the duty of the State Geologist, subject to the approval of the Commission, to organize and direct the work of the State Geological Survey in field and office; to determine the character, order, and time of publication of the reports of the survey, and to

direct the preparation, printing, and distribution of the same; to arrange for co-operative work with the various Federal and State scientific bureaus where such work shall redound to the interest of the people of the State; to appoint such associates, assistants, and employees as may be necessary to carry out successfully and speedily the work of the survey; to procure and have charge of the necessary field and office supplies and other equipment, and supervise the acquisition. care, and distribution of the collections of the State Geological Survey; and to perform such other work as may be necessary to the successful conduct of the survey. He shall prepare a report to the General Assembly before each meeting of the same, setting forth the progress and conditions of the survey, together with such other information as the commission may deem necessary and useful.

SEC. 5. *Be it further enacted,* That the said State Geological Survey shall have for its objects and duties the following:

1. A study of the geological formations of the State, with especial reference to their economic products, including coal, oil, gas, ores, fertilizers, building stones, road-making materials, clays, cement materials, sands, soils, forests, mineral and artesian waters, drainage of swamps, streams, and water powers, and other natural resources.

2. A study of the character, origin, and relations of the soils of the State, with especial reference to their adaptability to particular crops, the maintenance of soil fertility, and the conservation and utilization of supplies of natural fertilizers.

3. A study of the road-making materials of the State, with reference to their character, distribution, and the best methods of utilizing the same.

4. A study of the occurrence and availability of underground water supplies.

5. An investigation of the forests, streams, and water powers of the State, with especial reference to their conservation and development for industrial enterprises.

6. A study of the swamps and other nontillable lands of the State, with reference to their reclamation for agricultural purposes.

7. A study of the physical features of the State, with reference to their bearing upon the occupations, physical welfare, and intellectual pursuits of the people.

8. The preparation of special reports with necessary illustrations and maps, which shall embrace both general and detailed descriptions of the geology, topography, and natural resources of the State.

9. The preparation of special geologic, topographic, and economic maps to illustrate the structure, relief, and natural resources of the State.

10. The consideration of such other scientific and economic questions as in the judgment of the Commission shall be deemed of value to the people of the State.

SEC. 6. *Be it further enacted,* That the regular and special reports of the State Geological Survey, with proper illustrations and maps, shall be printed and distributed and sold as the Commission shall deem best for the interest of the people of the State and as said Commission may direct, and all moneys obtained by the sale of said reports shall be paid into the State treasury. The

said Commission shall be caused to be prepared a report to the General Assembly before each meeting of the same, showing the progress and condition of the survey, together with such other information as they may deem necessary and useful, or as the General Assembly may require; *provided, however,* that the Commission shall have the right to print and distribute said reports.

SEC. 7. *Be it further enacted,* That after having served the purposes of the Survey, all material collected shall be distributed by the Director to the educational institutions of the State in such manner as the Commission may determine to be of advantage to the educational interests of the State; *provided, however,* that if deemed advisable, the Commission may first use such portion as may be necessary to establish a permanent exhibit of the natural resources of the State. On the completion or discontinuance of the State Geological Survey, the Commission shall cause all records, notes, books, reports, charts, maps, manuscripts, instruments, and other equipment and property of the survey to be placed in charge of a suitable custodian to be held subject to final disposition by the General Assembly; *provided, however,* that any field or other equipment which the Commission shall deem it undesirable to preserve may be sold as the Commission may direct and the money turned into the State treasury; and, *provided further,* that the copies of the reports of the survey left on hand for distribution shall be distributed by the custodian in such manner as shall be for the best interest of the people of the State.

SEC. 8. *Be it further enacted,* That the said Commission is hereby authorized to enter into coöperation with the United States Geological Survey and other scientific bureaus of the Federal and State governments for the prosecution at joint expense of such work in the State as shall be deemed of mutual interest and advantage, and under such conditions as said Commission may deem to be for the best interest of the people of the State.

SEC. 9. *Be it further enacted,* That in order to carry out the provisions of this Act, it shall be lawful for any person or persons employed hereunder to enter and cross all lands within the State; *provided,* that in so doing no damage is done to private property.

SEC. 10. *Be it further enacted,* That for the purpose of carrying out the provisions of this Act, fifteen thousand dollars ($15,000) annually for the years 1910 and 1911, or so much thereof as may be necessary, is hereby appropriated out of any money in the State treasury not otherwise appropriated, and the State Treasurer is hereby authorized to pay out the same on the warrants of the Comptroller upon the presentation of the proper vouchers by the Chairman of said State Geological Commission; *provided,* that the appropriation made herein shall not be available until May 1, 1910.

SEC. 11. *Be it further enacted,* That this Act take effect from and after its passage, the public welfare requiring it.

Passed April 30, 1909.

WM. KINNEY,
Speaker of the Senate.

M. HILLSMAN TAYLOR,
Speaker of the House of Representatives.

Approved May 1, 1909.

MALCOLM R. PATTERSON,
Governor.

By-Product Coke Oven Opportunities in Tennessee

By A. H. Purdue.

Products from coal.—When bituminous coal is heated in ovens that do not permit the access of air, the following products are formed: Coke, coal gas, coal tar, liquid ammonia and benzol.

Coke is composed mainly of carbon (C) but it also contains small amounts of hydrogen (H), oxygen (O), nitrogen (N), and sulphur (S). In addition to these it contains more or less mineral matter, as ash. In making coke the other products; namely, coal gas, coal tar, liquid ammonia, and benzol, are driven off, as volatile matter. These are permitted to escape into the air and are wasted, or become by-products, depending upon the kind of oven used. A ton of bituminous coal will produce from .50 to .79 of a ton of coke, the amount also depending mainly upon the kind of oven used, though in part upon the character of the coal.

Coal gas is a complex mixture of gases and vapors, of which hydrogen and marsh gas (CH_4) are the chief constituents. Other constituents are carbon monoxide (CO), carbon dioxide (CO_2), olefiant gas (C_2H_4), tetrylene (C_4H_8), hydrogen sulphide (H_2S), and nitrogen; and there are traces of ammonia (NH_3), carbon disulphide (CS_2), cyanogen (CN), and oxygen. A ton of average bituminous coal will produce about 10,000 feet of gas.

Coal tar is a mixture of many different substances. These are separated into different products by chemical processes, and from these products are made coal-tar dyes, coal-tar medicines, perfumes, etc. The amount of tar that a ton of coal will produce varies roughly between 3 and 5 per cent. of its weight, or between 6 and 10 gallons.

Ammonia is one of the remaining substances after the coal tar has been removed from the volatile matter of the coke oven. It is recovered in forms from crude liquor to nearly chemically pure ammonia and by being converted into ammonium sulphate $(NH_4)_2SO_4$,

the principal use of which is in the manufacture of fertilizers. A ton of average coking coal will produce about 20 pounds of ammonium sulphate.

Benzol or benzene (C_6H_6) is obtained from the volatile matter of coke ovens, after the coal tar and ammonia have been removed. From it are made tuluol or toluene ($C_6H_5CH_3$), xylol or xylene $C_6H_4(CH_3)_2$, coal-tar naptha and other compounds of hydrogen and carbon which, like those named, are known as hydrocarbons. The benzol and tuluol, etc., form the basis for the coal-tar dyes, and from them also are made the high explosives.

Value of coal products.—The value of coal products varies with their character, with the local demands, and with the general market conditions, but the following table will perhaps give an idea of their average worth, omitting benzol, upon the value of which the writer is not informed.

Table of the average value of the products from one ton of coal, treated in a by-products oven

Coke, .70 of a ton, valued at $2.50 a ton	$1.75
Surplus coal gas, 5,000 ft.,* valued at .04 cts.	0.20
Coal tar, 10 gallons, valued at 2½ cts. per gallon	0.25
Ammonium sulphate, 20 lbs. at 2½ cts. per lb. (net)	0.50
Total	$2.70
Value without the coke	0.95

It should be repeated that the amount of the by-products from a ton of coal and their value is variable with time and place, but it is thought that the figures given are very conservative. Granted that they are, attention is called to the fact that the value of the by-products in the manufacture of coke is $0.95 for each ton of coal used. That is to say, this value is wasted unless some sort of by-product oven is used. If a company is using the beehive type of oven (which wastes all the by-products), and consumes the moderate amount of only 200,000 tons of coal a year for that purpose, we have the amazing loss of $190,000; and this does not include the benzol. The value of the surplus gas is estimated on a minimum of what it would bring for manufacturing purposes. Where there is domestic consumption, it probably would have a much higher net

*Approximately half the gas produced is used at the plant, in heating the ovens.

value. The gas consumed in heating the ovens, which is approximately 50 per cent of the amount produced, is not here taken into account, but it really should be credited to the plant. Eliminating the gas entirely from the computation, and counting only the coal tar and the ammonium sulphate, their value yet from 200,000 tons of coal would be $150,000.

There is yet another advantage of the by-product over the beehive oven. The former will make from 0.65 to 0.79 of a ton of coke to one of coal, while the latter will produce only from 0.50 to 0.55 of a ton of coke to one of coal. And again, the time required for burning in the former is less than half what it is in the latter.

Coke producers not to be censured.—Amazing as is the waste from the beehive oven in coke manufacture, the producers of coke are not to be censured for having used them in the past nor perhaps under certain conditions at the present time. The past has demanded iron, and the manufacture of iron in turn demanded coke. Until recently it was thought that coke made in the by-product furnace could not be used for metallurgical purposes, and it was mainly for such purposes that coke was manufactured.

The day of permissible wastefulness is past.—But now, there is a demand by the blast furnaces for coke from the by-product ovens, and there is a market for all the by-products. The European war has brought forcibly and painfully to our attention the fact that we have been dependent upon Germany for our dyestuffs; and the scarcity of dyestuffs brought on by the war has aroused our manufacturers and chemists to such activity that plants for their production are rapidly springing up in this country. The outlook is that we shall never again be dependent upon a foreign country for them. That the condition ever obtained is not to be blamed upon our manufacturers and chemists, for there has heretofore been no business incentive to produce dyestuffs. That we have not produced them is not because we could not, but because the business was not profitable.

Now that the domestic demand for by-products from coke exists, and doubtless will continue to do so, there is no longer any excuse for wastefulness, except possibly in isolated cases. This is realized by the producers of coke. They are not asleep to the possibilities open to them. They see that the by-product ovens will pay, and that they can not afford to do without them; but business changes usually have their difficulties, and the one from the beehive to the by-product

ovens is no exception to the rule. A company that has been making coke in beehive ovens has a large amount of money invested in them, and the change requires that this be sacrificed. Also, by-product plants are very expensive, and the capitalist hesitates and investigates before putting his money in them. Many coke ovens are located at the coal mines to save shipping, and there is no market for the gas.

These are some of the business considerations that confront the conservationist in his protest against waste. Still, his answer is that the pitiful waste must cease and that the conditions by which it can be stopped without unfairness to producers, must be brought about at the first hour it can be.

As stated above, all the possible by-products from coke go to waste from the beehive oven. The worth of this wasted material may be seen by reference to the above table of its value. The time has come when it seems not only a crime for any coke maker to permit this waste from his plant, but it is doubtful if any one has a moral right even to burn coking coal in the furnace that heats his home, when coke can be had for the purpose. Under normal conditions, this country imports annually about $10,000,000 worth of coal-tar products, to say nothing of the other by-products. With our large supply of coking coal, and with the protection that it appears the by-product industry can now rely upon, these should be produced at home in the future.

With the amount of coal coked in Tennessee in 1915 as 460,354 tons*' and assuming that the average value of the possible by-products from a ton of this is $0.95, then it follows that the waste in the State from that source in the year named was $437,336.30. As already stated, the manufacturers of coke have given more or less attention to saving their by-products. Some of them have even had their plants investigated and reported upon by experts, with the view of making the change, and have decided to make it as soon as practicable. Whatever may be the reasons for not having already made the change, it is certainly hoped that at least the larger coke producers will, at the earliest opportunity, abandon the beehive ovens with their deplorable waste, and substitute those that conserve the valuable products to our needs instead of allowing them to escape into the air to be lost forever.

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*From manuscript of the report of the State Mining Department for 1915.

History of coke ovens.— Most people are familiar with the condition for making charcoal, which is that the wood shall be burned without free access of air. When charcoal is intended for fuel, the wood is arranged in a conical pile around a central aperture, then covered with earth, and fired. In making coke, the same principle governs the process, and it appears that the first coke was made in the same way that fuel charcoal is made, except of course that bituminous coal was substituted for wood.

FIG. 1. Beehive coke ovens at LaFollette, Tennessee.

The first coke oven used was of the beehive type, and this is still common in America, though it seems to have been wholly discarded in Europe. The beehive oven is dome-shaped with a circular opening at the top, through which the oven is charged with coal. Those used in Tennessee hold about 7 tons of coal each. They are arranged in rows, as shown in the figure, and their individual shape does not show from the outside. They are charged through the circular openings, from cars that run along a track on top of the ovens. The time of burning is either 48 or 72 hours. When the process of distillation is complete, the coke is drawn through a door on a level with the floor of the oven. This is kept closed during the process of burning.

In the history of coke ovens, the beehive was followed by the retort oven. This is more complicated than the beehive, and is used in producing coal gas, in which case coke comes to be a by-product. It has the advantages of saving tar and ammonia liquor as by-products, of coking coal low in volatile matter, and in doing it in about half the time required by the beehive oven.

The development of by-product recovery seems to have been a gradual one from that of the retort oven used in the manufacture of coal gas to that of the present efficient by-product plant.

FIG. 2. By-product coke plant, Fairfield, Alabama.

Mr. H. Mansfield, superintendent of the Chattanooga Gas & Coal Products Company, Chattanooga, Tennessee, who has had long experience with by-product ovens, is the authority for the following statements on their introduction in the United States: The by-product industry began in the United States in 1894-5, the Cambra Steel Company at Johnstown, Pennsylvania, being the first to introduce by-product coke for metallurgical purposes. A second plant of 120 ovens immediately followed, and was located at Glassport, a short distance above Pittsburg. This was intended more as an experimental plant to introduce by-product coke to the blast furnace operator. Mr. Mansfield further says that the next plant to be built was

one of 400 ovens at Everett, Massachusetts, to supply gas for the city of Boston. This was quickly followed by 50 ovens at Hamilton, Ohio; 212 at Sharon, Pennsylvania; 200 at Sparrows Point, Maryland; 50 at Indianapolis, etc., with the result that perhaps 40 per cent. of the coke now made is from by-product ovens.

By-product ovens in the United States are increasing much more rapidly than the beehive ovens, but it is yet a deplorable fact that perhaps twice as much coal is used in the latter as in the former.

Coke ovens in Tennessee.—The following table gives the number and distribution of coke ovens in Tennessee in 1915:

Coke ovens in Tennessee in 1915*

County	No. of ovens	No. in blast	Name and office of company
Campbell	293	280	LaFollette Coal, Iron & Railway Company, LaFollette, Tennessee.
Grundy	214	90	Sewanee Fuel & Iron Company, Coalmont, Tennessee.
			Tennessee Consolidated Coal Company, Tracy City, Tennessee.
Hamilton	212	105	Durham Coal & Iron Company, Soddy, Tennessee.
Morgan	140	96	Brushy Mountain Coal Mines, Petros, Tennessee.
Roane	340	240	Roane Iron Company, Rockwood, Tennessee.
Total.....	1199	811	

All the ovens named in the above table are of the beehive type. In 1915 a by-product plant was built at Chattanooga, by the Chattanooga Gas & Coal Products Company, and put in operation in 1916. The total amount of coal coked in Tennessee in 1915 was 460,354 short tons. This made 247,571 short tons of coke,† which means that on the average the coke ovens in Tennessee produced .538 tons of coke to a ton of coal.

Example of business opportunities.—Of the coke plants of the State, the writer has seen only those at Rockwood and LaFollette. The conditions are much the same at the two places, but at the latter the geology is the more conspicuous, and for that reason it will be

*From manuscript of the report of the State Mining Department for 1915.
†Loc. cit.

taken as an example of the business opportunities that it would seem are open to the investor at the coke plants in Tennessee.

The LaFollette Coal, Iron and Railway Company has, at LaFollette, 293 beehive ovens. The company has made investigations into the advisability of installing a by-product plant, the report of which was placed in the writer's hands through the courtesy of Mr. A. D. Macfarlane, Assistant Manager and Chief Engineer. This report considers such questions as the general mine conditions, character of the coal, cost of coke production, coke from slack and from mixed coal, amount and value of possible by-products, and general business considerations.

Of these, only the amount and value of the by-products will be considered here. For determining this important matter, 100 lbs. of coal were sent to H. Koppers Company, Joliet, Illinois, to be tested in their ovens. This test showed that for each ton of coal charged into the ovens, the following by-products could be obtained:

Table showing possible products from one ton of LaFollette coal

Tar	63.60 pounds	or 8½ gallons.*
Free ammonia	9.00 pounds	This would produce 34.68 lbs. of ammonium sulphate.
Combined ammonia	.60 pounds	
Water	112.80 pounds	
Carbon dioxide	24.20 pounds	
Hydrogen sulphide	6.00 pounds	
Gas	345.40 pounds	or 11302 cu. ft.
Coke	1438.40 pounds	
Total	2000.00 pounds	

An analysis of the gas was as follows:

Illuminants	4.00 per cent
Carbon monoxide (CO)	7.00 per cent
Hydrogen	49.58 per cent
Marsh gas (CH_4)	32.85 per cent
Nitrogen	6.57 per cent
Total	100.00 per cent

The heat value of the gas is 627 B. T. U. per cu. ft. The value of the by-products is shown in the following table:

*The writer computes this as 6.63 gallons.

Table showing the value of the possible by-products from one ton of LaFollette coal

8½ gallons of coal tar at 2½c per gallon	$0.2125
34 lbs. of ammonium sulphate at 2½c per lb. (net)	.8500
5,000 cu. ft. of surplus gas at 4c per thousand (one-half the amount produced is used in heating the ovens)	.2000
Total value	$1.2625

The officials report that approximately 225,000 tons of coal are used annually by the Company, in making coke. The possible by-products on this coal would be worth, according to the test made, $284,062.50. This is the astonishing amount of 56.81 per cent. on a plant costing $500,000. Doubtless there are incidental losses connected with a by-product plant of which the writer is not aware, though it would appear that after deducting a liberal amount for interest on the investment, taxes, depreciation, labor, administration, and such other losses as might occur, there should remain a good net profit; but this is a business matter upon which the writer can not speak, and into which prospective investors would of course look.

However, it should be remembered that there are two points of gain not considered in the above calculation; namely, the greater amount of coke obtained from a ton of coal from the by-product oven, over that obtained from the beehive, which is from 10 to 20 per cent. On the basis of a consumption of 225,000 tons of coal with the maximum yield of 55 per cent in the beehive oven, the coke produced would be 123,750 tons. The same amount coked in the by-products oven, with the minimum yield of 65 per cent, would give 146,250 tons of coke—a gain of 22,500 tons. The other point of gain is that the by-product oven will take a charge of 13½ tons of coal, which will coke in 18 hours, while the beehive oven will take a charge of about 7 tons, which it requires either 48 or 72 hours to coke.

Possible use for surplus gas.—The tests show that a ton of the LaFollette coal will produce 11,302 cu. ft. of gas. Approximately half of this would be consumed in heating the ovens. In looking for a possible use for the other half, some officials of the company have suggested that it could be used in a central power station. Possibly this is the best use to which it could be put; but there are two raw materials in abundance, right at hand, that are staring the man in the face who is looking for a place to put money, asking him for investigation. These are as follows:

(1) The rocks immediately down the creek from the coke ovens consist of massive sandstone beds of Pennsylvania or Upper Carboniferous age, standing on edge, with beds of dark shale between them. Advantages for quarrying the shale could not be better, for it could be handled by gravity, there would be no water in the pit, and the sandstone beds on either side are strong enough to stand up, unsupported after the shale is removed from between them. A sample of this shale was taken by the writer from all parts of a bed, 40 feet thick. This bed had been exposed at the side of the railroad cut, so that the sample can be considered representative of it. The analysis is as follows:

*Analysis of shale 100 feet south of bridge at the coke ovens, LaFollette, Tennessee**

Soluble silica	27.4 per cent
Insoluble silica	31.9 per cent
Al_2O_3 (aluminum oxide, or alumina)	21.1 per cent
FeO, Fe_2O_3 (iron oxides)	5.7 per cent
Mn_3O_4 (manganese, as manganous-manganic oxide)	0.1 per cent
TiO_2 (titanium dioxide)	0.1 per cent
CaO (calcium oxide, or lime)	0.4 per cent
MgO (magnesium oxide, or magnesia)	1.4 per cent
Na_2O, K_2O (sodium and potassium oxides)	2.6 per cent
P_2O_5 (phosphoric oxide)	trace
S (sulphur)	trace
CO_2 (carbon dioxide)	0.7 per cent
Water and organic matter	1.4 per cent
Loss on ignition—water and CO_2	7.2 per cent
	100.00

So far as can be judged from an analysis, this would make good paving brick and sewer pipe. For purposes of comparison, there is herewith presented a table by Wheeler giving the chemical composition of paving brick shale as "deduced from fifty reliable sources":

*Analysis by Dr. Paul C. Bowers, Chemist of the Survey.

Composition of paving brick shales. (Wheeler)*

	Minimum per cent	Maximum per cent	Average
SiO_2	49.0	75.0	
Al_2O_3	11.0	25.0	
Ignition loss (H_2O, S, CO_2)	3.0	13.0	
Moisture (H_2O)	0.5	3.0	
Total non-fluxing constituents			87.0
Fe_2O_3	2.0	9.0	
CaO	0.2	3.5	
MgO	0.1	3.0	
Na_2O } K_2O }	1.0	5.5	
Total fluxing constituents			13.0
Grand total			100.0

Perhaps 250 feet down the creek from where the above LaFollette sample was taken, there is a bed of shale 150 feet thick, also on edge and with equally good quarrying advantages. This was covered with a thin layer of soil, and it was not convenient to take a representative sample for analysis, but in all probability it is equal to the sample taken, for the purposes named.

(2) About 200 yards south of the 150-foot bed of shale, and running parallel with it, there is a bed of limestone, known in geology as the Newman limestone, that supplies the flux for the blast furnace of the LaFollette Coal, Iron and Railway Company. This limestone, like the shales and sandstone, stands on edge and is 150 feet thick. The quarry is dry and all mining conditions are ideal, except for the unimportant fact that the beds being on edge make blasting less effective than if they were flat. Eight analyses of this limestone, taken from the records of the company, are as follows:

Analyses of limestone at LaFollette

1910	SiO_2	CaO	MgO	Al and Fe
March 5	2.04	51.2	2.98	2.76
March 12	1.72	50.8	2.85	3.19
March 19	2.60	50.6	2.64	3.10
March 26	2.76	51.2	2.36	3.08
April 9	2.26	51.2	6.20	0.80†

Concluded on p. 37.

*Mo. Geol. Surv., Vol. XI, p. 456.

†It appears that in this analysis there must have been a mistake in calculating the MgO and the Al and Fe. A. H. P.

April	17.....	2.68.....	54.7	3.41.....	1.80
April	23.....	2.40.....	51.05.....	2.45.....	2.00
April	30.....	3.18.....	50.92.....	2.74.....	1.11

A sample carefully taken by the writer across the quarry, was analyzed by Dr. Paul C. Bowers, with the following result:

Analysis of Newman limestone at LaFollette

SiO_2 (silica)	2.7 per cent
Al_2O_3 (alumina)	.3 per cent
FeO, Fe_2O_3 (iron oxides)	.5 per cent
MnO (manganous oxide)	trace
CaO (lime)	51.8 per cent=92.4 per cent $CaCO_3$
MgO (magnesia)	2.7 per cent= 5.6 per cent $MgCO_3$
SO_3 (sulphur trioxide)	trace
CO_2 (carbon dioxide)	41.9 per cent
Moisture (H_2O)	.1 per cent
Total	100.0

Adaptability of the materials for Portland cement.—For use in the manufacture of Portland cement, shales, "should be free from gravel and sand, as the silica present as pebbles or grit is practically inert in the kiln unless ground more finely than is economically practicable. In composition they should carry not less than 55 per cent of silica, and preferably from 60 to 70 per cent. The alumina and iron together should be not more than half as great as the silica, and the composition will usually be better if they are only one-third. Nodules of lime carbonate, gypsum, or pyrite, if present in any quantity, are undesirable, though the lime carbonate is not absolutely injurious. Magnesia and the alkalies should be low, preferably not above 3 per cent".*

No sandstone layers, pebbles, pyrite, or other injurious material was noted in the bed from which the sample of shale was taken for analysis, though gypsum and pyrite may occur in small amount. As may be seen by referring to the analysis, the amount of silica (soluble and insoluble), in this shale is 59.3 per cent. The amount of alumina and iron oxide is 26.8 per cent, which is only .45 as great as the amount of silica. Magnesia and the alkalies are low. It appears that this shale is admirably adapted to the manufacture of Portland cement.

*Eckel, Edwin C., U. S. Geol. Surv., Bull. 522, p. 56.

The limestone is gray, coarsely crystalline to compact, and in beds from 1 foot to 4 feet or more thick, these standing almost on edge. It probably would crush easily. The amount of silica, alumina and iron oxide combined is only 3.5 per cent, according to the above analysis by Dr. Bowers. The 51.8 per cent of CaO (lime) is equivalent to 92.4 per cent of $CaCO_3$ (calcium carbonate); the 2.7 MgO (magnesia) is equivalent to 5.6 per cent. of $MgCO_3$ (magnesium carbonate). The only constituent that throws doubt upon the adaptability of this limestone to Portland cement is the amount of magnesia which, according to the analysis made by Dr. Bowers, as well as those furnished by the Company, is a little high. As a rule, 2.5 per cent. is considered the maximum amount of magnesia, which is .2 per cent. below the amount carried by this limestone, as determined in this survey's laboratory. The disadvantage of this small excess probably could be overcome.

It will be seen from the above, that there probably are two possible uses for the surplus gas, one in the manufacture of brick and sewer pipe, and the other in the manufacture of cement, though a company contemplating the erection of a plant for either purpose should have a sufficient number of analyses and other tests made to thoroughly satisfy themselves about the adaptability of the material for the purpose desired. It is probable that both common brick and paving brick could be made of the shale. These products would not come in competition with the brick and cement manufactured at Kingsport, for they are on different lines of railroad, and would find a market in different territory. The Southern and the Louisville and Nashville railroads enter LaFollette.

Cost of installation.—The size of the plant that could be supplied by the surplus gas would of course depend upon the amount of coal consumed in making coke. This might be sufficient to accommodate both a cement and a brick plant, or only one. It is thought that a liberal estimate for the cost of installing a by-product plant is $500,000; a brick and sewer-pipe plant, $300,000; a cement plant, $1,500,000; the first two, $800,000; all three, $2,300,000.

Mineral products assembled at LaFollette and elsewhere.—It is very unusual for different mineral products that must be used in combination to occur together, as they do at LaFollette. Here, red iron ore, coal for coke and limestone for flux in the blast furnace, all occur within a belt only a few hundred yards in width. The lime-

stone and shale for cement, and the shale for brick and sewer pipe, occur in the same belt, making the assemblage of raw materials the more remarkable. The same conditions occur at Rockwood and, with the exception of the iron, at Soddy, at both of which coke is now manufactured in beehive ovens.

Shipping coal for coke manufacture.—In all probability there are good coking coals in Tennessee at points where there is no raw material for manufacture into finished products, and consequently no possible use for the surplus gas. In such cases the question comes up as to whether it would pay to ship the coal to the cities where it could be used in by-product plants, the surplus gas finding a market with the manufacturer and domestic consumer. The answer to this question depends upon such important considerations as the freight on the coal to the city plant, the freight on the coke from the plant to the iron furnaces, the quality of the coke and the demand for it, the value of the surplus gas, etc. If the price of coke for domestic use could be put low enough to attract the home consumer, and people could become educated to its general use, the result would not only be an economic saving in the broad sense, but the smoke nuisance would be stopped. Most of the smoke of which we so bitterly complain comes from the chimneys of our own residences.

As an example of the coal thus used and the waste from it, we might take the amount consumed annually in Nashville which, roughly approximated, amounts to 220,000 tons. According to the table given above, the value of the gas, coal tar, and ammonia from each ton of this coal, all of which goes into the air, is 95 cents a ton, or $209,000 for the whole amount consumed. This would be saved in a by-product plant.

With coke heating the home and gas the factory, our cities would rest beneath clear skies, our nostrils be relieved of the unpleasant odors of coal smoke, our lungs of its injurious effects, and the housekeeper made happy.

Recent Oil Development at Glenmary, Tennessee

By L. C. Glenn

During the past summer an oil well was drilled on the creek flats about three-quarters of a mile northwest of Glenmary, Scott County, Tennessee. The drilling began June 5th and was finished August 31st. The elevation of the well mouth is 1248 feet and is about five feet below the top of the Lee conglomerate which appears in good development in a low bluff on the north side of the creek a few rods west of the well. As seen here and traced for a mile and a half west, the top of the Lee is a typical soft, light colored to pinkish sandstone of medium coarseness and evenly laminated to cross-bedded. The log of the well shows this top member of the Lee to be 42 feet thick in the well. To this should be added about 8 feet for the upper part of the sandstone, making the bed about 50 feet thick in all. The base of the Lee was reached at a depth of 730 feet, making that formation 735 feet thick, when the five feet above the well mouth are added to the log. Then follow, in descending order, 220 feet of Pennington rocks, mostly red to dark calcareous clay shales with a subordinate amount of limestone. At a depth of 950 feet the St. Louis limestone was reached and 294 feet of it was penetrated, the well reaching the depth of 1244 feet from the surface, the 8 feet from 1232 to 1240 feet being oil-bearing. This oil-bearing layer is given in the log as "gray sand and small pebble". No sample of it could be secured to learn whether it is really a thin sandstone or not. It is suspected by the writer from analogy with the wells drilled in the last year at Oneida that the oil "sand" is really a limestone, that is perhaps dolomitic.

The log as given by the drillers, Sackrider and Fuller, is as follows:

Record of Pemberton Well No. 1

	Thickness	Top	Bottom
Soil	3 ft.	0 ft.	3 ft.
Hard white sand	42 ft.	3 ft.	45 ft.

Black slate	105 ft.	45 ft.	150 ft.
Hard white sand	155 ft.	150 ft.	305 ft.
Slate	130 ft.	305 ft.	435 ft.
Coarse loam sandstone	105 ft.	435 ft.	540 ft.
Black slate	7 ft.	540 ft.	547 ft.
Hard white sandstone, base of Lee	183 ft.	547 ft.	730 ft.
Slate and lime shells, top of Pennington	45 ft.	730 ft.	775 ft.
Red shale	20 ft.	775 ft.	795 ft.
Black slate	27 ft.	795 ft.	822 ft.
Dark lime	73 ft.	822 ft.	895 ft.
Red shale	13 ft.	895 ft.	908 ft.
Dark lime	22 ft.	908 ft.	930 ft.
Black slate, base of Pennington	20 ft.	930 ft.	950 ft.
Limestone, top of St. Louis	98 ft.	950 ft.	1048 ft.
White slate	3 ft.	1048 ft.	1051 ft.
Dark lime	93 ft.	1051 ft.	1144 ft.
Black slate	3 ft.	1144 ft.	1147 ft.
Gray sand	8 ft.	1147 ft.	1155 ft.
Hard white lime	77 ft.	1155 ft.	1232 ft.
Gray sand and small pebble, oil-bearing.	8 ft.	1232 ft.	1240 ft.
Hard white lime	4 ft.	1240 ft.	1244 ft.

Salt water was struck at 505 feet and a little show of gas at 1045 feet. On August 30th there were 640 feet of oil in the well and on August 31st, 700 feet. There was little or no gas with the oil.

The oil.—The oil is dark green in color. An examination by a private laboratory is reported as follows:

Distillation table of Glenmary oil

	Per cent	Gravity Baumé
Crude oil		38.4
Fraction up to 302°F	19	65.2
Fraction 302° to 380°	10	51.5
Fraction 380° to 550°	19	42.3
Residue at 550°	50	23.8
Loss	2	

Gasoline from crude Glenmary oil, refined

Up to 194°	30 per cent
212°	46 per cent
230°	58 per cent
248°	72 per cent
266°	78 per cent
284°	84 per cent
302°	88 per cent
320°	91 per cent

Concluded on p. 42.

338° .....93 per cent
356° .....95 per cent
374° .....96 per cent
420°, end point.....98 per cent

This examination shows the oil to contain a good percentage of high grade and intermediate gasoline. No test for sulphur seems to have been made. The Oneida oil, from about the same geological horizon, contained one-sixth of one per cent. sulphur. The oil doubtless has a paraffin base.

Yield.—A 250 barrel tank was provided and from the slight test so small a tank would furnish, the well will probably pump between 10 and 20 barrels a day.

Geological horizon.—The oil comes from an 8-foot bed in the St. Louis limestone 282 feet below the top of the formation.

Geological structure.—The rocks at Glenmary are part of a long monocline rising slowly to the west or west northwest. The rate of rise at Glenmary is between 30 and 40 feet per mile. No evidence was found of any fold or flattening or other interruption of this general rise of the rocks northwestward. No anticlinal or synclinal structure was discovered. The oil would seem to occupy a certain level in the rocks, having possibly been driven to its present position by salt water back of or below it. If so we would expect wells drilled down the dip of the rocks, that is to the east of the present well, to run into salt water sooner or later while wells drilled in a general northerly or southerly direction from the present well and so along the strike of the rocks, would reach the oil-bearing stratum at the same elevation as the Pemberton well and would have a better chance to strike oil. The safest rule to follow in making further development is undoubtedly to "feel out" the productive territory from the present well by other wells some 600 to 800 feet away and preferably on the same stratigraphic level rather than up or down the dip.

It is too early to predict just what will be the size or yield of the pool, but there would seem to be a chance for the development of an oil area at Glenmary. If the well now down proves on continuous pumping to hold up to a steady yield, there is no antecedent reason why much more productive territory may not exist there, for in much other territory in that general vicinity conditions are equally as favorable for the accumulation of oil, so far as any one can see, as at the well here described.

In this connection a comparison may be made of the record and log of the Strubbe well drilled in 1891 about one and a fourth miles nearly due west of the Pemberton well. This Strubbe well found some oil at 1233 feet depth but was not regarded as a paying well. Its elevation is about 1240 feet, and the well mouth is about 45 feet below the top of the Lee formation, or the conglomerate division of the coal measures. At 65 feet depth, 2 inches of coal was struck, and at 506 feet, there were 4 inches of coal. At 1128 feet a little gas was struck. The log is as follows:

Log of Strubbe Well, about two miles northwest of Glenmary, Tenn.

	Thickness	Top	Bottom
Alluvium	15 ft.	0 ft.	15 ft.
Shale, gray and black	55 ft.	15 ft.	70 ft.
Sandstone, gray	100 ft.	70 ft.	170 ft.
Sandstone and shale, dark gray	10 ft.	170 ft.	180 ft.
Sandstone, gray	40 ft.	180 ft.	220 ft.
Sandstone and shale, black	40 ft.	220 ft.	260 ft.
Sandstone, dark gray	60 ft.	260 ft.	320 ft.
Sandstone and shale, black	55 ft.	320 ft.	375 ft.
Sandstone, gray, base of Lee	305 ft.	375 ft.	680 ft.
Limestone, dark gray, top of Pennington	10 ft.	680 ft.	690 ft.
Shale and limestone, red and black	65 ft.	690 ft.	755 ft.
Limestone, gray	5 ft.	755 ft.	760 ft.
Shale and limestone, black	20 ft.	760 ft.	780 ft.
Limestone, black	25 ft.	780 ft.	805 ft.
Shale, black	20 ft.	805 ft.	825 ft.
Shale, red and black	25 ft.	825 ft.	850 ft.
Shale, black, base of Pennington	35 ft.	850 ft.	885 ft.
Limestone, gray and black, top of St. Louis	185 ft.	885 ft.	1070 ft.
Limestone, dark	166 ft.	1070 ft.	1236 ft.

The shale in the above log described by the driller as black is really the very dark gray shale characteristic of a part of the Pennington and is not a black carbonaceous shale, such as the Devonian or Chattanooga shale. The mouth of the Strubbe well is some 40 feet lower stratigraphically than the Pemberton well. In each well oil was found at almost exactly the same depth, but the oil in the Strubbe well came from a slightly lower horizon stratigraphically than that from the Pemberton well.

Properties of Molding Sand

By Robert E. Wendt*

Men engaged in the foundry business select their sand according to the class of work they wish to make. For light or thin castings, in order to make them smooth, the sand grains should be small; for large or heavy castings, the sand must be coarse, in proportion to the size or bulk of the casting.

Good molding sand is not uncommonly found along rivers and lakes in all parts of the United States. New York, Ohio and Kentucky are known as molding sand centers.

The composition of molding sand is about 80 per cent. sand and 10 per cent. clay. The sand grains should have sharp corners. There are always such other ingredients as lime, magnesia and some metallic oxides.

The sand must be cohesive when it is moistened to the proper degree and rammed about the pattern to sufficient hardness. It must stick together so as to stand handling in the flask, and must hold the metal in shape when poured; must be porous enough to allow the free escape of steam and gases that are generated when the molten metal is poured into the mold; must be refractory enough to stand the high temperature of melted cast iron, without fusing, but must bake a little from the heat, without fusing with the metal; and must readily peel from the casting, leaving it with a smooth, clean surface.

New sand, that is sand that has not been used for molding, is stronger than it need be. After the sand has been used awhile and burned a little, it will give better results. Generally castings made in partly burned sand will be smoother and the sand will leave them more freely than when it is new.

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*Mr. Wendt is Foundry Instructor, Purdue University. The purpose of this paper is to assist the members of the Survey and others in recognizing deposits of sand that may be used for molding. A. H. P.

The molder must look after his sand carefully when preparing it for use. After it has been used many times, the sharp edges become rounded, partly from wear and partly from the high temperature of the molten metal which causes slight fusing. Also, the clay will burn out. These two changes cause the sand to become weak unless new sand is added.

When castings are taken from the sand, some of it will adhere to them, and is therefore lost. This decreases the moulder's supply, he adds new sand to his heap, mixing it with the old. This builds up his sand and keeps it suitable for molding, and in this way he can use it over and over again, every day.

In order to make some castings smooth, it is necessary to make a special facing, which is put next to the pattern. For this purpose, such material as soft coal ground fine, resin, wheat flour, molasses, core compound and other materials are mixed with sand. After the mold is finished, it is painted or dusted with finely powdered graphite before it is poured.

Publications of Geological Survey of Tennessee Issued.

The following publications have been issued by the present Survey, and will be sent on request *when accompanied by the necessary postage.* Gaps in the series of numbers are of reports still in preparation:

Bulletin No. 1—Geological Work in Tennessee.

A. The establishment, purpose, object and methods of the State Geological Survey; by Geo. H. Ashley, 33 pages, issued July, 1910, postage, 2 cents.

B. Bibliography of Tennessee Geology and Related Subjects; by Elizabeth Cockrill, 119 pages; postage, 3 cents.

Bulletin No. 2—Preliminary Papers on the Mineral Resources of Tennessee, by Geo. H. Ashley and others.

A. Outline Introduction to the Mineral Resources of Tennessee, by Geo. H. Ashley, issued September 10, 1910; 65 pages; postage, 2 cents.

D. The Marbles of East Tennessee, by C. H. Gordon; issued May, 1911; 33 pages; postage, 2 cents.

E. Oil Development in Tennessee, by M. J. Munn; issued January, 1911; 46 pages; postage, 2 cents.

G. The Zinc Deposits of Tennessee, by S. W. Osgood; issued October, 1910; 16 pages; postage, 1 cent.

Bulletin No. 3—Drainage Reclamation in Tennessee; 74 pages; issued July, 1910; postage, 3 cents.

A. Drainage Problems in Tennessee, by Geo. H. Ashley; pages 1-15; postage, 1 cent.

B. Drainage of Rivers in Gibson County, Tennessee, by A. E. Morgan and S. H. McCrory; pages 17-43; postage, 1 cent.

C. The Drainage Law of Tennessee; pages 45-74; postage, 1 cent.

Bulletin No. 4—Administrative Report of the State Geologist, 1910; issued March, 1911; postage, 2 cents.

Bulletin No. 5—Clays of West Tennessee, by Wilbur A. Nelson; issued April, 1911; postage, 4 cents.

Bulletin No. 9—Economic Geology of the Dayton-Pikeville Region, by W. C. Phalen, for sale only, price 15 cents.

Bulletin No. 10—Studies of the Forests of Tennessee.

A. An Investigation of the Forest Conditions in Tennessee, by R. Clifford Hall; issued April, 1911; 56 pages; postage 3 cents.

B. Chestnut in Tennessee, by W. W. Ashe, issued December, 1911; postage, 2 cents.

C. Yellow Poplar in Tennessee, by W. W. Ashe, issued January, 1914; 55 pages; postage, 3 cents.

Bulletin No. 13—A Brief Summary of the Resources of Tennessee, by Geo. H. Ashley; issued May, 1911; 40 pages; postage, 2 cents.

Bulletin No. 14—The Zinc Deposits of Northeastern Tennessee, by A. H. Purdue; issued September, 1912; 69 pages; 30 illustrations, postage, 3 cents a number.

Bulletin No. 15—Administrative Report of State Geologist, 1912.

Bulletin No. 16—The Red Iron Ores of East Tennessee, by E. F. Burchard; issued November, 1913; 172 pages; postage, 8 cents.

Bulletin No. 17—The Water Powers of Tennessee, by J. A. Switzer; issued April, 1914; 137 pages; postage, 8 cents.

Bulletin No. 18—Administrative Report of the State Geologist, 1914.

Maps—Map of Lewis County, 1915; postage, 2 cents.
Geological Map of Tennessee, 1915; postage, 15 cents.
Map of Rutherford County, 1916; postage, 2 cents.
Map of McNairy County, 1916; postage, 2 cents.

"THE RESOURCES OF TENNESSEE."—This is a quarterly magazine, devoted to the description, conservation and development of the State's resources. Postage, 2c a number. The following are the volumes and numbers issued, with the titles of the principal papers in each number:

Vol. I. No. 1—The utilization of the small water powers in Tennessee, by J. A. Switzer and Geo. H. Ashley.

No. 2.—The Camden chert—an ideal road material, by Geo. H. Ashley.
The Fernvale iron ore deposit of Davidson County, by Wilbur A. Nelson.
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Tennessee to Have Another Great Water Power, by George Byrne.
Manufacture of Sulphuric Acid in Tennessee in 1911, by Wilbur A. Nelson.

No. 2—The Ocoee River Power Development, by J. A. Switzer.
Exploration for Natural Gas and Oil at Memphis, Tenn., by M. J. Munn.

No. 3—The Power Development at Hale's Bar, by J. A. Switzer.
Notes on Lead in Tennessee, by Wilbur A. Nelson.

No. 4—The Tennessee Academy of Science.
The Preliminary Consideration of Water Power Projects, by J. A. Switzer.
Lignite and Lignitic Clay in West Tennessee, by Wilbur A. Nelson.

No. 5—The Growth of Our Knowledge of Tennessee Geology, L. C. Glenn.

No. 6—On the Impounding of Waters to Prevent Floods, by A. H. Purdue.
Drainage Problems of Wolf, Hatchie, and South Fork of Forked Deer Rivers, in West Tennessee, by L. L. Hidinger and Arthur E. Morgan.
The Waste From Hillside Wash, by A. H. Purdue.

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No. 8—The Monteagle Wonder Cave, by Wilbur A. Nelson.
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No. 9—The Valley and Mountain Iron Ores of East Tennessee, by Royal P. Jarvis.

No. 10—The Iron Industry of Lawrence and Wayne Counties, by A. H. Purdue.
Some Building Sands of Tennessee, by Wilbur A. Nelson.

No. 11—Tests on the Clays of Henry County, by F. A. Kirkpatrick. Introduction, by Wilbur A. Nelson.
Barite Deposits in the Sweetwater District, by Herbert B. Henegar.

No. 12—The Soils and Agricultural Resources of Robertson County, by Reese F. Rogers.
The Iron Ore Deposits in the Tuckahoe District, by C. H. Gordon and R. P. Jarvis.

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The Gravels of West Tennessee Valley

By Bruce Wade

INTRODUCTION

Important deposits of gravel and clayey sands occur along the West Valley of Tennessee River in a belt stretching from the southern to the northern border of the State. Their distribution in unconnected areas extends about 40 miles east and 12 to 20 miles west of the river. They range in elevation from the top of the western edge of the Highland Rim of Tennessee, which is about 1100 feet above sea level, down to the bed of Tennessee River, approximately 300 feet above sea level, at the northern border of the State. As to age, these deposits may be separated into two major divisions. The older is correlated with the Tuscaloosa formation, the earliest of the Upper Cretaceous series in the Mississippi Embayment; the later was formed during a period extending from the time when the Tennessee River became fixed in its present course down to present time; that is, probably from Pliocene to Recent.

The gravels of this area have often attracted the attention of geologists, and their age has been variously assigned. Safford* gives a concise account of their occurrence and distribution, and considers them all as formed in one epoch and at least younger than the Cretaceous. Chamberlin and Salisbury† call attention to the fact that there are widespread gravel deposits on high levels in many regions in the Southern Gulf and Atlantic States, and say that these deposits are Pliocene in age. In 1905, L. C. Glenn made a study of the water resources of West Tennessee and Kentucky for the U. S. Geological Survey and in his report‡ on the geology of this area Professor Glenn gives a good account of the occurrence and distribution of these gravels and refers them to the Lafayette formation of the Pliocene. In 1913, H. D. Miser and N. F. Drake, while engaged in the

*Safford, J. M., 1869, Geology of Tennessee, pp. 434-438.

†Geology, Vol. III, pp. 301-308, 1906.

‡Glenn, L. C., 1906, U. S. Geological Survey, Water Supply Paper 164, pp. 40-43.

field work on the areal geology of the Waynesboro Quadrangle* showed that the thick gravel beds on the extreme eastern side of West Tennessee valley and in the southern part of the State are Upper Cretaceous in age. Recently an article by the present writer has been submitted for publication giving some observations on the occurrence of Tuscaloosa gravels as far north as Kentucky.†

During the summers of 1915 and 1916, while engaged in a study of the post-Paleozoic deposits of West Tennessee for the State Geological Survey, the writer had an opportunity of examining most of the important exposures of gravel in West Valley of Tennessee River. It is the purpose of the present preliminary paper to call attention to the extensive deposits of gravel in this area and to give a few observations on its occurrence, origin and age; and further to call the attention of highway engineers, who are interested in building roads in West Tennessee, to the widespread inexhaustible supply of material which may be used for the construction of gravel roads. A detailed account of these deposits can not be given here, but the State Geological Survey is engaged at present in preparing geologic maps of each county in this area, which will be published in the future, together with county reports, that will give in detail the location of all the important gravel deposits in the area herein considered, as well as numerous sections showing the stratigraphic relations of the various occurrences and other information that may be included in such reports.

On submitting this paper for publication the writer wishes to acknowledge his indebtedness to Professor E. W. Berry of Johns Hopkins University; Dr. A. H. Purdue, State Geologist; Professor L. C. Glenn of Vanderbilt University; and L. W. Stephenson, E. W. Shaw and H. D. Miser of the U. S. Geological Survey, for information and assistance given in the class-room, in the field, and in personal conferences for interpreting the relationships of these gravel deposits. Mr. C. R. Watkins, Jr., of the Tennessee Geological Survey, has furnished traverse maps of McNairy, Decatur and, in part, Hardin counties and the elevations of many points which have been of importance in this investigation. Mr. De Long Rice, Superintendent of the Shiloh National Park, has kindly given information in

*Drake, N. F., 1913, Resources of Tennessee, Vol. IV, No. 3, p. 107.
†Manuscript submitted to the Johns Hopkins Circular 1917.

regard to the cost and construction of gravel roads in the military park on the grounds of the Shiloh Battlefield.

GENERAL STATEMENT

Area discussed.—The region described lies for the most part in the eastern portion of West Tennessee, but includes adjoining areas of western Kentucky, northwestern Alabama and northeastern Mississippi. *West Tennessee Valley* is a name frequently applied to this region. Tennessee River rises in western Virginia, flows southwest across East Tennessee, then west across northern Alabama and finally north across West Tennessee and Kentucky, thus making two distinct valleys across the State, the eastern one sloping to the south and the western one to the north. The gravel deposits to be discussed in this paper lie for the most part on the side slopes of the western one of these valleys.

Basis for the paper.—As a basis for a report on the gravel deposits of the area named, the writer assisted in the field work for a folio report on the Waynesboro quadrangle conducted under coöperative arrangements between the U. S. Geological Survey and the Tennessee Geological Survey, and headed by H. D. Miser, in 1913. In 1914 the writer did areal mapping in Perry, Lewis, and Humphreys counties for the geologic map of the State compiled by Olaf P. Jenkins in 1915. During the summer of 1915 the writer was engaged in working out the areal geology of McNairy and Hardin counties. In connection with that work reconnaissance trips were taken into Tishomingo County, Mississippi, and Lauderdale County, Alabama. In the summer of 1916 he did areal work in Decatur County and made reconnaissance trips into Benton, Henry, and Dickson counties of this State and into Calloway, Trigg, Marshall, and McCracken counties of Kentucky.

Topography.—As regards topography, the region under discussion is highly dissected and uneven. The elevations range from about 1100 feet down to 286 feet above sea level. The area lies along the northeastern edge of the Mississippi Embayment along the border where the unconsolidated Cretaceous and post-Cretaceous clays, sands and gravels overlap the Paleozoic limestones and cherts. The eastern edge of this area includes the western margin of the Highland Rim of Tennessee. The Highland Rim stands about 1000 feet above sea level and is probably a remnant of a plain that was worn

down to nearly a common level before the deposition of the Cretaceous, and again in Tertiary times. This plateau, before the present physiographic conditions took form, probably extended westward into the region now constituting the plain of West Tennessee. The Tennessee River system in its northward course has intrenched itself (cut its bed down) more than 400 feet beneath this ancient plateau. remnants of which now remain only on the east side of the valley. The western side of the valley has been eroded more than the eastern side because it was composed of softer rocks (Cretaceous and Tertiary) and because it was unfavorably located between two master streams, the Mississippi and the Tennessee. It has consequently been cut down to a rolling plain which has a general elevation along the eastern margin from 400 to 680 feet above sea level. So under the present physiographic conditions West Tennessee Valley extends northward across the State and separates the plain of West Tennessee from the Highland Rim of the central part of the State.

In its northward course across the State, Tennessee River crosses the southern boundary about the middle of the southern limit of Hardin County and about 12 miles west of the eighty-eighth meridian. From this point it bears to the northwest and then to the northeast to the northwest corner of Wayne County, where it intersects the eighty-eighth meridian, which it follows in a general way from this locality to the northern limit of the State, passing between Decatur, Benton and Henry counties on the west and Perry, Humphreys, Houston and Stewart counties on the east.

Numerous creeks and small rivers flow into the Tennessee from both east and west. The largest and most important tributary in this part of its course is Duck River, which rises in the eastern part of the Highland Rim and empties into the Tennessee near the southern border of Humphreys County. On the western side the largest tributary is Big Sandy River which rises in Henderson County, flows nearly parallel to the Tennessee and empties into it near the northern border of the State.

Tennessee River and its tributaries are deeply intrenched; that is, they have cut deep valleys into the formations over which they flow. That part of the system which lies wholly in the Cretaceous and Tertiary formations has broad valleys with well developed terraces at different levels, while that part which lies in the areas where the rocks are almost wholly the Paleozoic limestones and cherts, has nar-

row valleys. These two types of valley topography are well illustrated in both the master stream itself and in its tributaries. In central Hardin County the Tennessee is cutting through an area where the Cretaceous-Paleozoic contact is for the most part below the present drainage, and the valley there is wide. Hills that stand up 200 feet or more above the river are very rare near it and are not frequent as isolated hills nor as a continuous valley wall for 8 or 10 miles on either side of the river. The present flood-plain itself is from 2 to 5 miles wide in the vicinity of Savannah. But even in this region the valley is not so wide as further south, for both up and down stream the Paleozoic rocks rise and the valley narrows into a canyon-like one with a flood plain often less than a quarter of a mile wide and with no broad terraces. Hills 300 feet above the river stand within a mile or less of either bank. Many vertical clifts of limestone and chert rise 150 feet or more from the edge of the water and form interesting scenery from northern Hardin County almost to the northern border of Houston County. In the extreme northern part of the State and in western Kentucky the valley becomes wider again, for in that region the soft rocks form the valley. As a result, there is a broad development of terraces west of the river extending as far west as Puryear in Henry County and still farther west in Kentucky.

The tributaries of the Tennessee that flow in from the east have narrow valleys in the Paleozoic rocks. On the west side of the river, the streams flowing into it rise on the Cretaceous and Tertiary formations but become intrenched in the Paleozoic rocks near their mouths. This is true of all the creeks except those in the west-central part of Hardin County. As a result of this the upper parts of the creeks and rivers in the unconsolidated sediments have wide bottoms. "Second bottoms", and other terrace levels are also widely developed. Examples of such secondary streams are White Oak Creek, Beech River and Big Sandy River.

Geology.—The above remarks on the topography are only general. The valleys and terraces will be described in greater detail in considering their history. As stated above, the formations of West Tennessee and extreme western Kentucky may be divided for discussion into two major groups— the consolidated Paleozoic rocks and

the unconsolidated post-Paleozoic rocks. A general subdivision of these two groups is as follows:

Unconsolidated Rocks	Recent	Alluvial clays, sands and gravels
	Pleistocene, Pliocene	Stream clays, sands, gravels
	Eocene....	Wilcox sands
	Eocene....	Midway clays
	Upper Cretaceous.....	Ripley sands
	Upper Cretaceous.....	Selma clays
	Upper Cretaceous.....	Eutaw clays and sands
	Upper Cretaceous....	Tuscaloosa gravels
Consolidated Rocks	Mississippian.....	shales, cherts and limestones
	Devonian.....	shales, cherts and impure limestones
	Silurian.....	limestones
	Ordovician.....	limestones

Gravels.—The gravels of West Tennessee Valley fall naturally into two groups, the Tuscaloosa group and the Pliocene-Pleistocene-Recent group. These two groups, though widely different in age, occupy the same general section of the State. Deposits of the younger group in a few localities may be seen resting upon beds of the older group; however, the occurrence of the Tuscaloosa gravels is for the most part farther east than that of the latter ones.

TUSCALOOSA GRAVELS

Age and general description.—The Tuscaloosa formation is the basal or oldest member of the Upper Cretaceous series in the eastern Gulf Region of the Mississippi Embayment. In western Alabama and eastern Mississippi this formation consists of irregularly bedded clays, sands and gravels having an estimated total thickness of 1000 feet. In Professional Paper 81 of the U. S. Geological Survey, L. W. Stephenson has readjusted the names of the Upper Cretaceous formations in this region and has defined the Tuscaloosa with reference to the other formations (Eutaw, Selma and Ripley) of this series.

Toward the north the Tuscaloosa deposits become much thinner and are made up almost entirely of conglomerates which contain little sand and clay. Professor E. W. Berry has made a study of this series and has found evidence in the fossil plants that the clays, in the basal part of the formation in the region of maximum thickness, are more ancient than plant-bearing clays that occur in the conglomerates about Iuka, Mississippi, where the formation becomes much

thinner. He shows that an Upper Cretaceous estuary existed for a long time in western Alabama before it transgressed northward.

Distribution in Tennessee and Kentucky.—Until recently the Tuscaloosa formation was thought to thin out entirely in the vicinity of the Tennessee-Alabama line. In 1913 H. D. Miser mapped the areal Geology of the Waynesboro Quadrangle of Tennessee and found that the Tuscaloosa was 150 feet* thick and extended over a large part of Wayne County. Subsequent work by the Tennessee Geological Survey showed that remnants of the Tuscaloosa gravel occur in places on the Highland Rim of Tennessee as far

FIG. 1. View of Tuscaloosa gravel on the Savannah-Gillis Mill road, 4 miles west of Gillis Mill, Hardin County.

north as northern Lewis County.† Farther north the writer, during the past summer, observed undescribed occurrences of the Tuscaloosa formation which show that the sediments of this transgressive phase of the Upper Cretaceous exist in a chain of local outlying areas across the State of Tennessee and as far north as a point on the ridge west of Canton, Kentucky.

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*Drake, N. F., "Economic Geology of the Waynesboro Quadrangle", *Resources of Tennessee*, Vol. IV, No. 3, p. 107, 1913.

†Wade, Bruce, "Geology of Perry County and Vicinity", *Resources of Tennessee*, Vol. IV, No. 4, p. 173, 1914.

An important link in this chain are the gravels which occur locally along the Nashville, Chattanooga and St. Louis Railway between McEwen and Tennessee City and capping the higher hills in this part of Dickson County, Tennessee. A cut on the railroad about two miles east of McEwen shows, resting on chert of the St. Louis formation, about 30 feet of very compact hard white chert gravel which is typical of the Tuscaloosa occurring in the belt across the State. No paleontological evidence has been obtained from the gravels about McEwen to determine the age of these deposits, but after a study of the lithology as well as the geographic and topographic relations, the Tuscaloosa age of the McEwen gravels can hardly be doubted. These gravels are made up of well rounded water-worn pebbles, most of which are 1 inch or less in diameter, but many are larger, ranging up to cobbles 6 inches in diameter. Many are spherical, and in this respect they differ from the river gravels which are common in terraces along the western Tennessee Valley, and which are often flat, elongated, and subangular. Small discoidal quartzite pebbles are often conspicuous in the terrace conglomerates. The Tuscaloosa conglomerates consist for the most part of pebbles and boulders derived from the Mississippian cherts which are common in this part of the Mississippi basin. Water-worn sandstone and iron oxide pebbles have not been observed in the Tuscaloosa gravels. This is another feature which serves to distinguish the Upper Cretaceous gravels from the more recent terrace ones in this part of the Embayment Region, even though the latter may rest directly on the former as is frequently the case in West Tennessee Valley.

South of McEwen, as stated above, the isolated Tuscaloosa gravel areas may be traced along the Highland Rim across Lewis County into Wayne and Hardin counties and farther into Mississipppi and Alabama where they are overlain by marine Eutaw deposits and fossil evidence may be obtained.

As above stated, the Tuscaloosa extends also north of McEwen. About 3 miles west of Canton in Trigg County, Kentucky, at a point just east of where the Fulton and Nashville Highway crosses the divide between the Tennessee and Cumberland rivers, is an exposure of about 30 feet of Tuscaloosa gravel overlain by 10 feet of Eutaw sand. The locality is about 7 miles east of the Upper Cretaceous belt as shown on the Geological Map of Kentucky.* This exposure

*Sellier, L. M., "State Map" Kentucky Geological Survey, 1915.

is probably more than 300 feet above the waters of the Tennessee and Cumberland rivers. This divide is a northern extension of the western part of the Highland Rim of Tennessee and it is probable that further study of the plateau between the Canton and McEwen localities will reveal isolated occurrences of Tuscaloosa that would form an almost unbroken chain of the remnants of this formation from Kentucky across Tennessee into Mississippi and Alabama, where it is normally developed.

A study of a map of the Upper Cretaceous belt of the eastern Gulf Region* shows that the Tennessee River flows from the east into the Cretaceous area in northwestern Alabama and then takes a northerly course just east of the Cretaceous area across Tennessee and Kentucky. The geological map shows that the wide Tuscaloosa belt in western Alabama and eastern Mississippi disappears entirely just north of where this river flows into the area. In the same part of the State the Eutaw belt is shown to become abruptly narrow and disappears much before it reaches the Southern border of Kentucky. Recent observations of the Tennessee Geological Survey have shown the occurrence of the Eutaw and Tuscaloosa farther north. These occurrences indicate that the Tuscaloosa formation, though probably not so thick and widespread as in western Alabama and eastern Mississippi, was at one time an important formation and covered large areas in Tennessee and Kentucky, and that the Eutaw formation also extended farther north and east. But during the erosion of West Tennessee Valley the Tuscaloosa has been almost entirely removed toward the north. The Eutaw formation has also been much eroded but to a less extent.

The accompanying sketch map shows the general areas across the State once occupied by the Tuscaloosa formation, which is now represented by only isolated occurrences except in the extreme southern part of the State.

POST-CRETACEOUS GRAVELS

Origin.—The post-Cretaceous group of gravels lies on the slopes of the valleys of the West Tennessee drainage system and is of stream origin. These gravels occur for the most part as terrace deposits which mark various flood plain stages of the Tennessee and

*Stephenson, L. W., "Cretaceous Deposits of the Eastern Gulf Region". U. S. Geological Survey 1914, Prof. Paper 81, map.

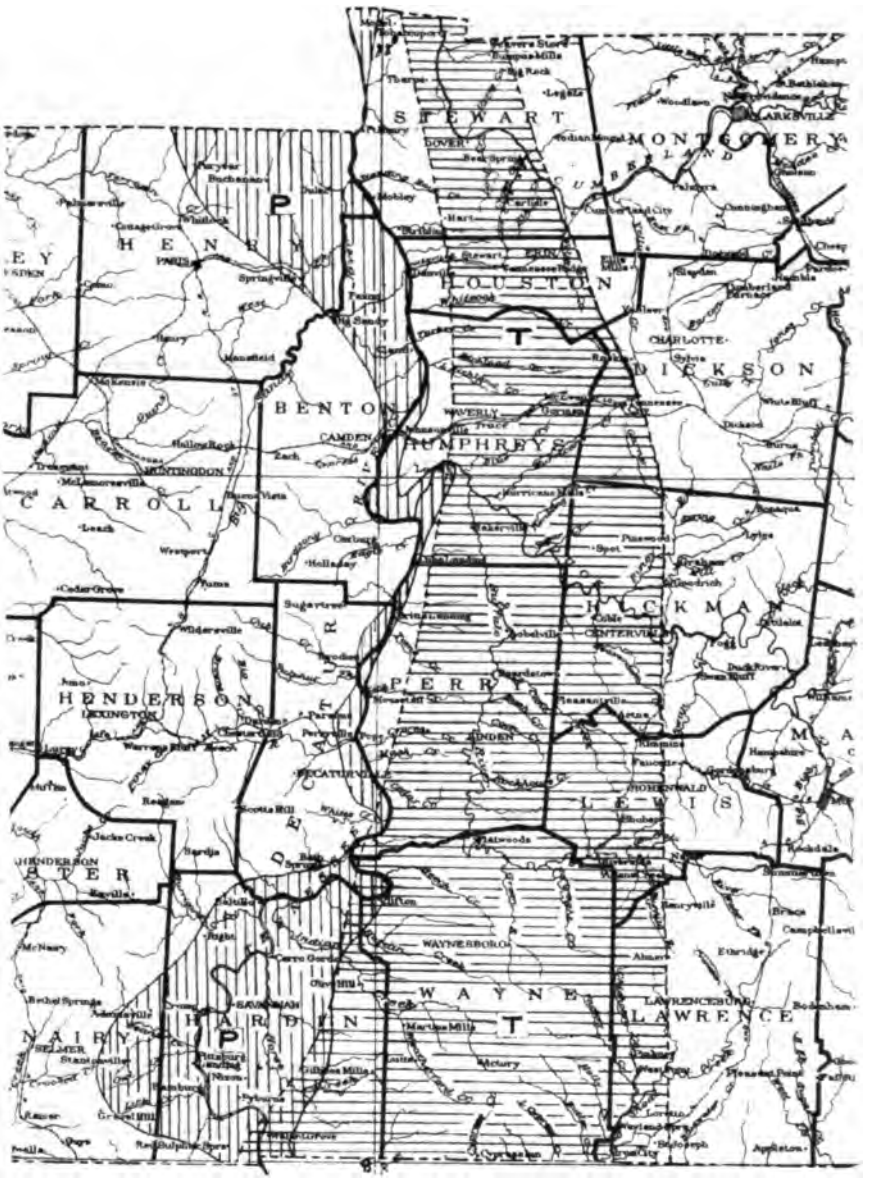

FIG. 2. Map showing the distribution of the Tuscaloosa and post-Cretaceous gravels in West Tennessee and adjacent part of Middle Tennessee. TT, area in which the Tuscaloosa gravel occurs, in isolated patches. PP, area of post-Cretaceous gravel.

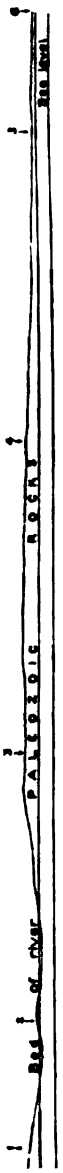

FIG. 3. Showing the surface of the Paleozoic rocks along West Tennessee Valley.

1. Tennessee-Mississippi line
2. Savannah
3. Perryville.
4. Camden
5. Fort Henry
6. Kentucky-Tennessee line

its tributaries dating probably from late Tertiary to Recent. The streams of the Coastal Plain are regarded as having taken their present general courses in Pliocene time.* After Miocene time the Coastal Plain was eroded into broad shallow valleys having approximately the same positions as those of the present streams. These valleys were filled by the deposition of Pliocene alluvial sands and gravels, and near the coast the deposits were extended across the interstream areas. This filling formed broad plains at successively lower levels as the erosion proceeded. The recent work of Matson, Berry and Shaw shows that important deposits mostly of stream origin occur in the southern part of the Gulf Coast Plain states, covering wide areas and extending far up the valleys of the streams which empty into the Gulf. In the West Tennessee Valley there are isolated occurrences of river gravels on the outer-most and upper walls of the valley, that were deposited probably during the Pliocene when the Tennessee had a much wider valley. These isolated terraces have an elevation of as much as 800 feet above sea level in some localities. They have suffered much from erosion but are no doubt remnants of once very broad flood plains.

In the above discussion of the Tuscaloosa group of gravels, it was shown that the unconsolidated post-Paleozoic deposits extended farther east than their present general distribution. And, further, when the Tennessee was first fixed in its present course across this part of the State it was eroding the unconsolidated Cretaceous sediments, and it was not until subsequently that erosion brought the bed of the river down on and into the hard Paleozoic strata that now hold most of its course in a narrow canyon-like valley. The wide outlying Plio-

*Matson, G. C., U. S. Geological Survey, 1916, Paper 98, L., p. 173.

cene terraces on the highest points in the area, formed before and soon after the river began its intrenchment in the Paleozoic rocks, show that the Tennessee at this period had a wide valley in which it meandered back and forth like a typical coastal plain river.

Successive elevations during late Pliocene and Pleistocene soon caused the river to cut through the thin unconsolidated Cretaceous sediments capping the middle Tertiary peneplain in this region. The surface of the Paleozoic rocks beneath the Cretaceous is a broad dome with its highest points in the middle of the northward course of the Tennessee through the State, as shown in Fig. 3. For this reason, and also from the fact that the river bears a little eastward in northern Hardin County and west again near the northern border of the State, it began first to cut into the hard Paleozoic strata in the intermediate portion of its northward course across the State. Thus early in its history the Tennessee fell to the lot of having to cut a channel through chert and siliceous limestone in the region of the northern part of Hardin and Wayne counties, and Decatur, Perry, Benton, Humphreys and Houston counties, while in the southern part of Tennessee and again in the northern part of the State and in western Kentucky, it was cutting unconsolidated gravels, sands and clays. In the latter regions wide valleys were eroded in the less resistent sediments. An erosion progressed and the channel become more deeply intrenched in the hard rocks, the bed of the river came to lie less and less on the Cretaceous deposits and more and more on the Paleozoic rocks, so that now, almost the entire northern course of the Tennessee is hemmed in by these. At present, the Paleozoic-Cretaceous contact is nowhere below the water of the Tennessee in its northward course, except in the local acreas in middle Hardin County, Tennessee, and just southeast of its mouth in McCracken County, Kentucky.

This relation and areal distribution of the hard and soft rocks explain the existence of the two wide valley regions in West Tennessee Valley, and why the earlier stages of these valleys were much wider than the more recent ones, as mentioned above under the discussion of the topography. Such relations are well adapted to the development of terraces. And a preliminary study of the distributions of

the stream gravels along the western Tennessee shows that their development is greatest in the two areas which coincides with the two wide valley regions.

Occurrence.—Thus the post-Cretaceous gravels fall naturally into two groups for discussion: Those in the McNairy-Hardin county region and those of the northern Tennessee and western Kentucky region. Both groups are of river origin and, though they owe their origin to slightly different physiographic conditions, the results produced are essentially the same.

The McNairy-Hardin county gravels were deposited in terraces of different levels in wide plains formed in this region of soft sediments while the river was laboriously cutting a narrow gorge in hard rock both up and down stream from this area. The lower narrow walls of hard rock on either side of the trough-like channel served as a barrier which hindered the widening of the valley in that part of the river's course. This produced a ponding effect of the waters rushing into the wide valley region and bringing with them heavy loads of gravel gathered from the siliceous trata in regions of high gradient, up-stream in northern Alabama. This ponding and retarding of the stream's velocity caused a deposition of load at various levels, according as the lowering of the valley continued. The waters of the Tennessee thus unloaded in the wide valley region of McNairy and Hardin counties were drawn off through the narrow trough-like channel across the middle part of the State. This channel led into the lower wide valley region in the northern part of Tennessee and western Kentucky. As the river cut its bed down through the rocks of this narrow cannel, its velocity and carrying power in the ponded part of its course increased so that a part of the great loads of gravel that were at first put down in that area was easily transported down-stream through the channel and deposited in the relatively quiet water of the lower, expanded portion of the valley, in Kentucky and Tennessee.

This lower wide valley region, at the time the river was around the 600-foot contour, more than 200 feet above the present channel, included much of western Kentucky and extended beyond Puryear in Henry County, Tennessee. Later stages were more restricted, since the stream soon became intrenched in the Mississippian chert of that region.

The ponding effect which produced the deposition of so much detritus in this lower wide valley was not due to any barrier of hard rocks, as in the McNairy-Hardin county area, but merely to the normal wide valley conditions near the mouth of a large mature stream flowing in soft sediments. The Tennessee empties into the Ohio not a great distance from the locality where the latter flows into the Mississippi, so all three of these streams have had an effect, either directly or indirectly, upon the alluvial deposits that cover most of western Kentucky and extend up the Tennessee Valley into Henry and Benton counties, Tennessee.

It is not the purpose of the present paper to give a detailed account of the areal, stratigraphic and topographic relations of the Tennessee River terraces, but mainly to call attention to the fact that there are important economic gravel deposits along West Tennessee Valley. Their general distribution has been given in Fig. 2, and an attempt is made to explain the origin and distribution from their relation to the hard and soft country rocks in the valley region. The State Survey plans to prepare maps and reports of the various counties in and adjoining Tennessee Valley that will give in detail the areal and stratigraphic relations of these gravels, which have already been mapped in McNairy, western Hardin and Decatur counties.

The terraces of West Tennessee Valley are discontinuous. Stream terraces are more complex than those formed along the sea-shore, and can not be correlated up and down stream with great certainty. When a stream sinks its channel into its flood-plain, it does not follow that a terrace remains on each side. Where the stream's deepened channel is in the middle of its flood-plain, there is, temporarily, a terrace on either side; but whenever the deepened channel is at one margin of its flood-plain, a terrace remains on the other side only. The latter has no doubt been the case in the formation of many of the terraces along West Tennessee Valley. Even where continuous at the outset, terraces soon become discontinuous, for all processes of erosion on land conspire to destroy them. A stream is likely to meander on its second and later flood-plains as on its first and highest one. Whenever the meanders on its second flood-plain reach the borders of the first flood-plain, the terrace at that point disappears, and since the meanders are continually migrating, terraces are continually disappearing‡. Owing to the underlying hard strata many

‡Chamberlin and Salisbury, Geology, 1914, vol. 1, p. 199.

of the early wide terraces that were laid down on the post-Paleozoic strata have been defended* as the streams became further intrenched in the hard rocks.

Regarding the age of the post-Cretaceous gravels, those occurring at the highest levels are probably Pliocene, as has been stated above, ranging down through Pleistocene to the Recent deposits now being formed as gravel bars and islands at the mouths of the large creeks and rivers flowing into the Tennessee from the east. Very few fossils have been found in the stream terraces of West Tennessee, and as yet no paleontological evidence has been obtained from terraces above the 500-foot contour. It is probable that the age of the various terraces can not be determined with assurance until they are shown on topographic maps, which have not yet been made.†

PRELIMINARY GROUPING AND CORRELATION OF THE TERRACE GRAVELS

For the purpose of a short preliminary discussion the terraces of the wide valley region, lying for the most part in Hardin and McNairy counties, may be divided into the following groups. The oldest and highest are given at the bottom of the column which reads up through the successively younger deposits to the recent alluvium at the top:

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*Davis, Bull. Mus. Comp. Zool., Geol. Ser., Vol. V, pp. 282-346.

†With such maps, the problem of the age of the stream deposits of the whole of West Tennessee, whether put down by the Tennessee or Mississippi or their tributaries, would be simplified. The terraces in West Tennessee Valley should be readily correlated with those of the lower Ohio and the Mississippi, and these in turn tied up with the definitely known Pliocene and Pleistocene terraces of the Gulf Region. Another line of evidence which would aid in this correlation would be obtained by tracing the river terraces northward up the Mississippi and Ohio and observing their relations with the glacial deposits. The reconnaissance work of E. W. Shaw for the U. S. Geologcal Survey, for the purpose of studying the physiography of the Mississippi Embayment region, will no doubt yield valuable information in regard to the stream deposits of this part of the United States.

Table of Tennessee River terraces

		Locality of typical exposure
Recent	Flood plains or aluvium	Tennessee bottoms
Pleistocene	Plain a little above the average high water mark or second bottoms	Hamburg
	Terraces about 420 feet in elevation	Saltillo, Savannah
	Terraces about 500 feet in elevation	Stantonville, Adamsville
	Terraces about 600 feet in elevation	Pebble Hill, Michie
Pliocene	Terraces between 620 and 800 feet in elevation	Pine hills in eastern and southern Hardin County

Pliocene gravels.—The terraces between 620 and 800 feet in elevation have been much eroded and occur only in isolated areas far out from the river in the wide valley regions but comparatively close to it where the valley is narrow. The highest gravels observed by the writer where elevation was definitely known in the area under discussion, are just below the Tennessee line in Lauderdale County, Alabama, on the dividing ridge between Bumpus Creek and Manbone Creek. Along this ridge there are deposits of sand and small gravel up to 30 feet thick, resting uncomfortably upon the lower strata of the Eutaw sand. On the ridge east of Manbone Creek similar deposits occur and here they rest upon the Tuscaloosa gravels. The distinguishing features of these conglomerates, even though they are in contact, have been pointed out under the discussion of the Tuscaloosa gravels. The elevation of these deposits as shown by the Iuka topographic sheet of the U. S. Geological Survey is from 780 to 800 feet above sea level. Similar deposits, situated at elevations a little lower may be traced at irregular intervals across the eastern side of Hardin County.

On the western side of the valley along the Tennessee-Mississippi divide no such elevations occur, so that the ancient divide between these streams, which at one time must have been greater than 800 feet, has been lowered by erosion, and the highest terraces have been destroyed. The highest river terraces known to the writer on the western side of the valley occur along the Hamburg and Iuka road and in the region north of Yellow Creek in Tennessee, and south-

ward in Mississippi to Short Creek. These deposits are made up of sands and small quartzite pebbles, and occur at an elevation from 630 to 650 feet above sea level. It seems reasonable to believe that higher terrace deposits at one time occurred west of the 630-650 foot terrace—deposits that would match up in general elevation with the 780-800 foot terraces in the eastern part of Hardin County and

FIG. 4. Pliocene terrace gravel on a ridge 700 feet high, two miles west of Lowryville, Hardin County, on the Savannah-Florence road.

northeastern Lauderdale County, Alabama. In a few places in McNairy and Chester counties, points in the Tennessee-Mississippi divide stand up above 650 feet in elevation. Some of these points are capped with surficial material consisting of reworked Ripley sands, many deposits of which contain a noticeable layer of small quarzite pebbles near the base. It is the opinion of the writer that these quartzite pebbles were derived by reworking processes of small streams from a once existing high terrace on the west side of the valley,

comparable with the 780-800 foot terrace on the eastern side. Such a terrace situated, as it must have been, on a basement of unconsolidated post-Paleozoic sediments, with tributaries of such master streams as the Mississippi and Tennessee, working toward it on both sides, would be destroyed more readily than the defended high terraces on the eastern side of the valley.

Terrace deposits between 620 and 700 feet in elevation are well developed on the hills east of Nixon and Pyburns in eastern Hardin County. Farther north in the same county they occur at a greater distance from the Tennessee on the hills east of Horse Creek. A few isolated occurrences of river gravels are known farther north in the narrow valley regions in Decatur and Perry counties. In this region their development is not extensive and the known occurrences are relatively very near the river.

The material of these terrace deposits consists largely of small quartz and quarzite pebbles and clayey sand. The pebbles as a rule are well-rounded and some are discoidal like beach shingle. There are no quartzite or quartz country rocks in the vicinity of West Tennessee Valley, so these gravels were probably derived from the conglomerate horizons in the Pennsylvania series occurring in the northern part of Alabama and East Tennessee. The work of H. E. Gregory shows that gravel in quantity is carried 30 to 40 miles by streams of high gradient, and under favorable conditions, portions of a gravel bank may be transported a few hundred miles*. The size and shape of the pebbles in the high terrace deposits were probably little effected in transportation by the river. The well rounded and discoidal shapes no doubt were determined before their deposition in the Pennsylvanian. The similarity brought out by a comparison of pebbles from these highest terraces with pebbles from the Lee conglomerates of the Cumberland Mountains of Tennessee and Alabama is striking. So it seems reasonable to think that the highest terrace deposits in West Tennessee Valley represent in part reworked Lee conglomerate gathered by the Tennessee River and its tributaries farther up stream.

Pleistocene gravels.—In both the lower and upper wide valley regions there are important terrace deposits around the 600 foot con-

*Gregory, H. E., 1915, "The Formation and Distribution of Fluviatile and Marine Gravels"; Am. Jour. Sci., Fourth Series, vol. XXXIX, no. 233, p. 494.

tour. They are best developed on the west side of the river in west Hardin and McNairy counties, and in Henry County in the northern part of the State. There are isolated occurrences in the counties on the east and in the intermediate regions, but no very extensive ones. This group of fluviatile deposits ranges from about 620 feet in the southern part of the State to about 575 feet or less in the northern part. There are typical occurrences of these deposits at Michie and Pebble Hill in McNairy County, the ridge west of Coffee Bluff and Right in Hardin County, and east of Cerro Gordo in the same county; also, in the broad flatwoods region about Puryear, west of Buchanan, and in a ridge about three miles southwest of Dulac, all of which are in Henry County. The Henry County terraces of this group are about 600 feet in elevation and are as high or nearly as high as some of the terraces of the same group in the upper wide valley region.

The lithology of the terraces around the 600 foot contour is quite different from that of the older ones. The pebbles of the younger gravel deposits are much coarser and the per cent of chert is much greater than in the higher terraces. Many of the chert fragments are angular and subangular. Large boulders are common, and angular fragments of St. Louis chert, with maximum dimensions as great as 18 inches, have been observed in the base of the terrace material on the southern part of Pebble Hill, a locality more than 15 miles away from any occurrences of St. Louis chert in place. In the same Pebble Hill locality limonite geodes commonly 12 inches in diameter, that were probably derived from the Ridley ferruginous clays occurring a few miles to the west, are common. Chert cobbles four or five inches in diameter are common, but the majority of the pebbles average less than 2 inches. Small quartz and quartzite pebbles are common and probably are derived from the reworking of the older terraces. Sand and clay form a good portion of the 600 foot terraces, especially on the western side of the valley where it was brought in by creeks from the western sand and clay hills.

The 600 foot terrace deposits are often 50 feet in thickness. They rest on an uneven surface of rocks ranging from Eocene to Ordovician in age. The coarsest sediments occur near the base, and toward the top they are finer. From 2 to 6 feet of clayey loam on the top of these deposits indicates a rather extended stage of quiet flood plain deposition.

The coarse sediments at the base of the 600 foot terrace may be interpreted as formed under conditions of steep gradient and rigorous climatic changes. Freezing no doubt was a factor in the breaking up of the chert beds into fragments that are of transportable dimensions. Floating ice may be proposed to explain the occurrence of the very large fragments at great distances from their normal occurrences. There seem to have been considerable changes in conditions of sedimentation between the 600 foot terrace deposits and those of the 630-800 foot group. And further the deposits of the latter group seem to have been formed at a time when the climate was milder and more uniform. For these reasons the group of ter-

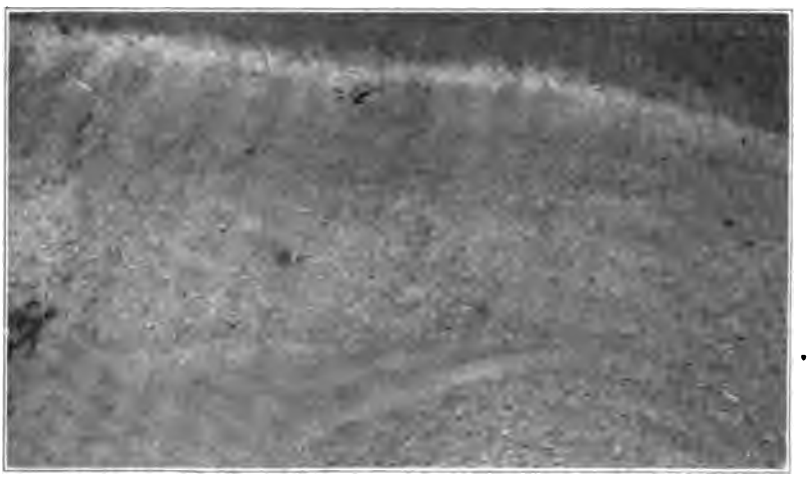

FIG. 5. Pleistocene terrace deposits in Hardin County, showing a lens of sand in the gravel, and a thick layer of soil above the gravel. This is characteristic of Pleistocene terraces in West Tennessee.

race deposits occurring in the vicinity of the 600 foot level are regarded as the initial stage of the Pleistocene and should be separated from the higher terraces which are probably Pliocene in age.

The next lower and younger group of terraces are those that occur near the 500 foot level, ranging from about 470 to 530 feet in elevation. These deposits are typically exposed in the lower wide valley region of McNairy and Hardin counties and may be correlated with widespread river deposits in the lower wide valley region of western Kentucky. Terraces about this elevation are common in

the upland regions of the creeks and rivers that head on the west side of the Tennessee-Mississippi divide and flow westward into the Mississippi. The terraces of this group are typically developed in Shiloh National Park, Hardin County, on a plateau about 475 feet in elevation, that extends westward to beyond Stantonville in McNairy County. Farther down-stream on the western side of the river is another plateau of this group of about 500 feet in elevation extending from Crumps westward beyond Adamsville. Other terraces of this group occur both to the north and south in the western valley and on both sides of the river.

This group of terraces occurs farther "streamward" than the older ones and have not been so much eroded as the higher benches, yet these Pleistocene flood-plains are greatly dissected by streams that have sunk their channels as much as 80 or 100 feet into them. In thickness and lithology, this group of terraces is very similar to those about the 600 foot level. On the west, the 500 foot terraces extend up the creek valleys, and in those regions they are made up entirely of sand and clay with perhaps a few pebbles that may have been derived from one of the more ancient terraces lying farthermost from the river, and not entirely obliterated at that time. The few pebbles occurring in the sand and clay terraces along the streams flowing west on the western side of the divide probably originated from the same source, as the head waters of the tributaries of the Mississippi pushed farther eastward across the ancient divide and into the highest terraces of the Tennessee.

A few fragments of fossil plants were collected from the base of the terrace on which Adamsville is situated, from a locality just west of the town. These were submitted to Professor Berry of Johns Hopkins University, for study. Only one species was determinable and that was a Pleistocene oak.

The third group of Pleistocene terraces occurs at an elevation of about 420 feet, or a little less, above sea level. A typical representative of this group is the plain on which Savannah is located. This plain is in the central part of Hardin County and is about 5 miles wide and 10 miles long. The deposits making up this terrace are from 20 to 40 feet in thickness and consist of gravels, sands and clays. Erosion has injured this less than either of the preceding Pleistocene terraces, yet it has been dissected by streams which have sunk their channels 10 to 30 feet below the base of the terrace mate-

rial. Down-stream from the Savannah plain there are various other terraces that may be correlated with this group. The region about Saltillo in Hardin County, Husksburg in Humphreys County and wide areas in western Kentucky represent flood-plain stages of the Tennessee at this cycle. Many of the plains of this group are about 400 feet in elevation.

A fourth terrace group and the youngest of those regarded as Pleistocene in age in the upper wide valley region are the "second bottoms". These are relatively young terraces that occur only 10 to 25 feet above present high water stage of the river. The plain

FIG. 6. Erosion in the Savannah terrace, one-fourth mile east of Paulk, Hardin County. This view shows the stratification of the gravel and the thick deposits of sandy soil overlying it.

about Hamburg in Hardin County is very typical of this group. The second bottoms are little dissected and the base of the river deposits is rarely exposed. In many localities they slope gradually toward the river and merge into the flood-plain with no intervening scarp. They are covered by a thick deposit of fertile loam which conceals the underlying gravel. Second bottoms are widely distributed up-and-down West Tennessee Valley.

An important feature of all the Pleistocene terraces in the West Tennessee Valley is the thick accumulation of soil on top of the coarse sand and gravel. The origin of this soil can be explained as

an accumulation during a silt-forming stage of deposition which persisted for a greater or less time before the stream lowered its channel and drew its waters away. This soil which caps the various terraces is porous and easily tilled. It is productive but not extremely fertile, for it lacks the strength which characterizes bottom soils even though it was once an alluvium, because it has been exposed to leeching processes so long that much of its fertility has been removed. It is a soil that can be built up readily by the proper agricultural methods and is in general more desirable for farming purposes than much of the land of the surrounding regions. For such reasons the areas of the Pleistocene plains have been important

FIG. 7. The Savannah plain, three miles southeast of Savannah.

in the settlement of this part of the State. Most of the villages and towns in West Tennessee Valley are situated on these various terraces. Some of these are Savannah, Saltillo, Crump, Right, Pittsburg Landing, Hamburg, Nixon, etc., in Hardin County; Adamsville, Stantonville, Michie and others in McNairy County; Thurman in Decatur County; Hucksburg in Humphreys County; Puryear in Henry County; and many of the towns in western Kentucky, among which are Murray, Benton and Paducah.

In concluding this discussion on the Pliocene-Pleistocene terraces, it should be stated that in this area, terraces occur intermediate in

elevation and not fitting into any of the groups given above, due to the complexity of river terracing. After this preliminary study, however, it is the opinion of the writer that some such grouping as that proposed above will be borne out when the terraces are shown on good topographic maps.

The Recent deposits include the present flood-plains along the Tennessee and its tributaries. These plains are more or less developed either on the one side or the other of the river throughout its northward course across the State. These plains are generally known as "bottoms" and are very fertile. The bottoms are practically all in cultivation and produce good crops except when a midsummer flood occurs and this is very rare. The widest development of the bottoms is in central Hardin County about Savannah where the alluvian plain is, in places, four or five miles wide. The upper portion of the alluvial plains is made up of a rich loam deposited as silt. Well borings in the alluvium show gravel and coarse detritus in the bottom of these recent deposits which are often 30 feet in thickness. At the present stage the Tennessee is not depositing gravel widely over its flood-plain but only in its channel near mouths of large creeks and rivers, where they form islands or bars in the bends of the river. In the upper portions of the creeks and rivers that empty into the Tennessee from the east, great thicknesses of gravels are accumulating. A typical example of this is on Indian Creek just east of the Hardin County line in Wayne County. In this region there is a wide valley of gravel with practically no soil on it and every freshet brings down tons of new gravel. Such conditions on a larger scale no doubt existed along the Tennessee in the earlier stages of the formation of the present alluvial plains and at various times during the Pleistocene in the formation of the several groups of terraces at different elevations. In general the present stage of the Tennessee seems to be that part of the cycle favorable for the accumulation of silt—a stage similar to those in which the thick soil accumulations on top of the gravels took place in the various Pleistocene terraces.

GRAVELS OF WEST TENNESSEE VALLEY AS ROAD MATERIAL

Quantity and character of the gravel.—The gravel deposits of West Tennessee Valley contain an almost inexhaustible supply of road material. All the counties lying along this valley are rich in

this product and in this respect have a very great advantage over the counties farther west where sands and clays prevail. In the latter counties the problem of road rock is a serious one and can only be solved by transporting gravel or other material into these counties from distances of a hundred miles or more at very great expense. The counties along the Tennessee, on the other hand, have excellent material for constructing highways, widely distributed. Every road in Hardin County might be made into a good gravel road without having to haul the gravel more than one or two miles except possibly in the northwestern part where it might in places may be necessary to haul it four or five miles. The quality is good, and many of the deposits are of such nature as to be applied to the road beds without screening or crushing. The supply is enormous. Hardin County alone might supply road material for all of West Tennessee and then hardly miss the gravel from its vast deposits. The same statement might well apply to more than one of the other counties along the Tennessee.

The Tuscaloosa group of the gravels is most extensively developed in Wayne and Hardin counties, but these extend northward in isolated occurrences in a broad belt across the State. The gravel of this formation in places is coarse and free from clay and in some pits it is often necessary to screen the material before applying it to a road. The screening separates the boulders and larger pebbles from the fine pebbles, making two grades of material which serve for the first and second application in constructing a gravel road. In most localities the Tuscaloosa gravel is so sorted naturally that coarse and fine material occur in separate parts of the exposure and screening is unnecessary. On account of the lack of clay and sand in the Tuscaloosa gravel, it makes an excellent railroad ballast and has been used extensively for this purpose in northern Mississippi and to some extent along the N., C. and St. L. Railway in Humphreys and Dickson counties. In general, however, the Tuscaloosa gravels have not been extensively utilized either in building roads or railroads in Tennessee, as they have in northern Mississippi.

The post-Cretaceous terraces along the river in the West Tennessee Valley are of great importance in road building in that part of the State. These terraces not only furnish material for the road itself, but on account of the even surface of the terrace plain and the sub-stratum of gravel, roads can be built and maintained at little

cost. As a rule, the best roads in this valley today occur along the terrace plains and are very much in contrast to the roads in the same region along the several other geologic formations. This is not because the roads on the terrace plains have received more attention, but because good roads have almost been made by nature along the terrace plains. The excellent gravel roads in the Shiloh National Park in Hardin County were made of the Pleistocene gravel taken directly from the terrace deposits upon which they were built.

Besides their use for roadbeds, these gravels may be used as a filler for concrete in building bridges and culverts. The use of steel and wood for such purposes may be abandoned except for reinforcement, in which case gravel would become the main constituent in the construction of some roads. Much of the gravel of the region is clean and free from clay and may be used as it occurs for concrete. But other deposits are mixed with sand and clay and should be washed or screened before being used as a filler for concrete.

What can be accomplished in the way of road building with these gravels is well shown by the roads in Shiloh National Park. These roads might well be taken as models and should be studied by those considering the building of gravel roads in this part of the State. Mr. De Long Rice, Superintendent of Shiloh Park, who has kindly furnished the Survey with the information on the roads of that park given in the letter below, will no doubt be glad to answer any further inquiries from those interested in building roads in counties adjoining Hardin County:

WAR DEPARTMENT

OFFICE OF THE SHILOH NATIONAL MILITARY PARK,
Pittsburg Landing, Tenn.
Jan. 24, 1917

Bruce Wade, Asst. Geologist,
State Geological Survey,
Nashville, Tenn.

My dear Sir:—

I have your letter of 8th instant. The graveled roads of this Park, 27 miles in all, are made entirely of gravel just as nature mixed it. There has never been a rock crusher on the Reservation, nor has one been needed.

The quality of gravel which we consider the very best, is that which has sufficient clay in the mixture to make it cement well when rolled. This we find in abundance on the grounds of the Park.

The only preliminary work necessary to get into the average pit is to find where it faces out in the side of a hill, and dig in. As the work progresses,

it is usually necessary to move anywhere from one to five feet of dirt from the top of the ground.

I think our roads, when properly shaped and rolled may be justly called first class highways. They do not give off the offensive dust which is peculiar to the limestone road. A good rain rather improves them, than hurts them.

I think about $2100.00 would cover the average cost per mile of our 27 miles.

The cost of up-keep is comparatively small. If a watchful system of break prevention is followed the cost is surprisingly low—that is, to be on the look-out for the little breaks in the surface caused by washes or sand pockets or ill use, and mend them before they become serious, always taking advantage of the proper weather conditions to reroll, and above all things, to so drain on either side that water can not stand and soak into the margins of the roads and make them soft.

The greatest enemy we have to meet is the deep freeze, to which no road is impervious. Such freezes, however, are very rare in this section. When they come, the only remedy is to drag and roll as soon as the road is dry enough for the roller not to pick up.

Drainage is the best weapon against the freeze, as the wetter the road is when the freeze comes, the greater the damage.

The roads of Shiloh are constantly praised and appreciated by those who use them, not alone because they are facilities for seeing and studying the battlefield, but also because they are driveways as beautiful as may be found in the greatest parks of the country. Lying mostly in the shadows of this historic forest, they are ideal throughout the summer, and as good as the best in the winter.

Sincerely yours,
(signed) De Long Rice,
Secretary and Superintendent.

GRAVEL ROADS

The following discussion of gravel roads is compiled largely from text books on highway engineering and a few personal observations:

General characteristics—Gravel roads seem to occupy an intermediate place between those of earth and broken stone, in the tractive force required, character of surfacing, and cost of construction.

On a well-made gravel road a horse is able to pull just twice the load he can draw on a dirt road, while this is only about one-half of what may be drawn on a macadam pavement. Gravel well applied makes a surface far superior to dirt, but does not possess the wearing qualities of broken chert, and for this reason gravel roads are most frequently built where gravel is accessible, where a covering other than earth is required, where the loads and traffic are light, and where the cost of broken stone is prohibitive. That is to say, gravel roads are best suited to country highways and park drives.

When stone roads are either impossible or impracticable, either because of the lack of suitable material in the vicinity, the excessive cost of the stone, or from some other reason, gravel, if properly laid, will make a very superior substitute.

Selection of gravel.—The gravel selected for road-building will generally be that most conveniently located, thereby introducing the possibility of great variety, for with hauls, greater than a mile and one-half, the item of transportation so increases the cost of construction that in such a case highway engineers recommend crushed chert. For this reason the Camden chert, which is a superior road rock to the water worn gravels, has been used in building roads in Madison and other counties in the western part of the State where all the rock has to be transported for a long distance.

The gravels of West Tennessee Valley consist of small stones of chert, quartz and quartzite, more or less worn and rounded by water action, and varying in size from that of a pea to pebbles two or more inches in diameter, and usually associated with ferruginous sand and clay that acts as a binder to hold the stones together. To be a serviceable and satisfactory road metal, it should possess the following characteristics:

The pebbles themselves must be hard, to resist the abrasive action of horses' hoofs and wagon wheels, and tough to withstand the blows of the horses' feet. The tougher and harder the stones, therefore, the longer will they wear. For this reason, whenever possible, care should be taken to select gravel pits where the gravel is not disintegrated, which is rarely the case with the gravels under discussion.

Between pebbles and binder there should be such a relation that all the voids in the stones are completely filled, and in a manner to give the maximum cementing effect. If this disposition of material or ratio is exceeded, the binder must necessarily take some of the wear, a function which it is not supposed to perform, and to which it is unsuited, while if not maintained, the bond will be weak and fail to hold the stones together.

Finally, the binder itself must possess to a marked degree the property of cementing the stones together, as otherwise the smooth pebbles move under traffic, similar to a mass of loose stone, and there is little stability in the pavement.

The binder may consist of loam, clay, iron oxide, silica, sand, or one of a number of other materials, but that most generally found

mixed with the stone is clay. Where the climatic conditions are favorable, this forms a very satisfactory bond, but with excessive rains or continued dry spells the cementing properties are quickly lost. In hot dry weather the lack of moisture and heat causes the clay to crack, leaving the pebbles as so many loose stones on the surface, while in wet weather the rain turns the clay to mud in which the stones soon disappear under pressure of the wheels.

Probably the best loam binder is one in which the clayey cement is very tenacious, and used in such quantity that the gravel will stick to the shovel enough to bother the workmen in handling it. If the gravel contains from three to ten per cent. of chert as well, the binding power will be further augmented as the latter is easily crushed and possesses superior cementing qualities.

The mechanical bond in material composed of angular fragments, is an important factor in the consolidation of either gravel or broken stone roads, the reason being that the irregularities and corners adjust themselves to each other in such a manner as to become wedged or locked together. For a somewhat similar result, in using gravel, the size may vary between about ½ inch and 3 inches, so that the smaller particles may fit into the interstices formed by the larger. Material smaller than ½ inch is too easily crushed in the pavement to be of much service, and larger than 3 inches tends to make the road rough. For this reason much of the Tuscaloosa gravel had best be screened and the coarser portion applied first and then covered over with the finer portion.

Gravel will be found to vary quite considerably, both in regard to the character of the stone and the quality and quantity of the binder present. River and seaside gravel are hardly ever so good as that from pits, because the smoothness of the stones permits them to turn under pressure, even when associated with a good binder. A gravel deposit may be passed upon by an inspection of it in the pit. If it stands with a vertical face, is compact, free from strata of sand (except a highly ferruginous sand), hard, needs a pick to dislodge it, and breaks in chunks, it will make an excellent road surfacing and require no further treatment. That containing ferruginous clay, together with sharp angular stones, is exceptionally good, as exposure to the air hardens the binder and produces the more complete consolidation of the material.

Usually the gravels of Tennessee River occur in beds containing pebbles fairly uniform in size so that no screening is necessary, but where this is not true, screening is necessary to remove the larger stones or the excess of earthy material or both. Two screens are employed, one passing material under 2¾ inches in diameter, and the other ¾ inch diameter. That which passes the smaller screen may be advantageously used as a final dressing while that retained from the larger screen may be used as a foundation, or crushed to smaller sizes. Screening, however, has a marked tendency to remove more of the binder than is desirable, and should be resorted to only when absolutely necessary. In the state-aid roads of Massachusetts where screening has been employed, the material is sized into ½ inch, 1¾ inch, 2¾ inch stone. These are spread in courses, the larger on the bottom, each layer being separately sprinkled and rolled as in the building of stone roads. Pebbles failing to pass the largest screen are sent to the crusher and again sized with the other gravel.

Drainage.—The complete and satisfactory drainage of a gravel road is essential and perhaps more important than with any other class, as the material, particularly the binder, is so easily displaced by water flowing over the road.

The purpose of the covering should be to form a smooth, hard, impervious surface, and so distribute the load that the foundation may be able to resist the pressure without failure and consequent rutting of the surface.

If water is allowed to remain in the ruts and hollows, the subgrade soon becomes softened, the binder loses its properties, the pebbles become loosened and the wheels cut through the subgrade. The drier the subsoil the firmer it will be and the better able to perform its function as a foundation. In fact, gravel on a soft wet base is practically useless, as it is readily forced into the mud below. Because a gravel road is less pervious, and sheds more water than one of dirt, the side ditches or drains should be both wide and deep—deep so that they may drain the subgrade of the roadbed well, and wide so that they may successfully care for the water diverted toward them. On steep grades the ditches are paved with cobble to prevent erosion. In Shiloh National Park, thin layers of conglomerate, formed by the cementing of pebbles by iron oxide in the shape of

rough flagstones or thick crusts, have been successfully utilized in making curbs on steep grades.

The longitudinal grade, from the standpoint of drainage, should be as small as possible, as gullies are quickly formed by the water flowing along the axis of the road and the binder and pebbles are washed away. In such cases, the crown is made correspondingly high, to get the water off the roadway and into the side ditches as soon as possible.

Under normal conditions the crown need not be so great as that employed in earth roads, for the water meets less resistance on the smooth surface of the gravel and reaches the ditches with a much smaller grade. A crown of ¼ to ¾ inch per foot of width or a rise at center of 1-50 the half width of wheelway is quite satisfactory.

The crown, however, depends very largely on the traffic, grade, and method of repairs, and for each set of conditions should be modified to suit. For example, on highways where the traffic is excessive, the crown is proportionally increased; first, because the greater the haulage the greater the amount of wear to the surface between periods of repair, and second, because ruts are more quickly made, retarding the flow of water which the crown must counteract.

Construction.—There are two general methods of building gravel roads, known as "surface construction" and "trench construction".

Surface construction is perhaps very much less satisfactory than the other because it requires less care in the work. In its crudest form it simply means that upon the old and unprepared roadbed a certain amount of gravel is dumped or strewn with the hope that traffic will consolidate it into an impervious pavement. This may be the case with very exceptional conditions; that is, where the roadbed is dry, hard, and well drained, and where the gravel is of such character that it binds well and quickly under the action of wagon wheels and horses' hoofs. This is often the case along the terrace plains of West Tennessee Valley, where the roadbeds are hard and well drained and much of the gravel is so ferruginous that it binds readily. Highway engineers are inclined to regard the surface method of construction a bad practice and only a makeshift at best. It is true that the Massachusetts Highway Commission has found gravel roads thus built in excellent repair after twelve years of surface, but this is unusual. The factors there have been care-

fully studied and found extremely favorable, as is true with many of the terrace plains of Tennessee.

On the contrary, the more care and preparation the original dirt road receives for the reception of the gravel covering, the better will it serve its purpose and the less it will cost for maintenance and repairs. The roadway, therefore, should first be properly graded, crowned and rolled to secure a firm, even surface, and the drainage carefully inspected, both as to the side ditches and surface drains, to see that the water is capable of being carried away as soon as possible. With such assurance, the gravel may be placed upon this as a foundation, being distributed over the surface in successive layers three to six inches deep. Each course is liberally sprinkled with water to insure speedy consolidation, and a road roller of ten tons is then used to perfect this. Should depressions develop during the rolling, more material must be spread upon such places, until, after a continuance of the process, the entire surface has been brought to the proper grade. If the consolidation is satisfactory, a second layer may be applied and treated in the same manner, the operation being repeated until the pavement is of the required thickness.

In some cases the traffic alone is allowed to perform the function of consolidating each course of material, but is not nearly so satisfactory, as it introduces foreign matter between the different layers, thus preventing a firm bond, and requiring much time to produce bonding. Unless the subgrade is drained properly and prepared to receive the gravel, frost and rain easily affect the foundation so that some months may elapse before the road comes to a very satisfactory condition.

The most critical period in the life of a gravel road is when traffic is first admitted to it, as then ruts are quickly and easily formed to remain as permanent defects unless repaired at once.

Some highway engineers adopt the following method in the construction of gravel roads: The bed is examined for low, wet and weak spots, and carefully prepared as a foundation, by removing objectionable material, laying drains, digging ditches, and thoroughly rolling, to receive the gravel to be placed upon it. This consists of a bottom course of screenings of the required depth, with a surfacing coat of one-inch gravel mixed with considerable binder above it. The whole road is then rolled until it becomes hard and

smooth, being well watered during the operation to assist consolidation.

Trench construction varies but little from the other form except in the fact that a trench is excavated of the required width and from eight to ten inches deep for the purpose of holding the gravel in place by means of the shoulders at the sides. The bottom of the trench or foundation for the gravel, prepared as in the previous case, may be flat or correspond in section to that of the surface of the road, the latter requiring less material.

The advantage of this over the other method is in the fact that the shoulders hold the gravel in place and prevent its thinning out at the center by working over to the sides. The material is applied as in surface construction.

In either form of construction, it is better that the gravel vary uniformly between ½ inch and 3 inches so that the voids between the larger pebbles may be filled by the smaller ones. If this is not the case, screening should be resorted to, so that material over 2½ or 3 inches and less than ½ inch may be rejected. The larger size may be used as a foundation upon which the other is placed, and when so used should be rolled and consolidated to a depth of about 4 inches before the smaller size is applied. This is put in layers, each being thoroughly sprinkled and rolled, while the top layer is mixed with an excess of binder.

Experience of authorities on road construction has shown that where the gravel is screened, excellent results are obtained, and that while the roads wear more quickly than macadam, due to ravelling, this is not serious. Such roads are more easily maintained than others.

Gravel on earth roads.—Frequently the application of a three or four-inch layer of gravel to an earth road will greatly improve the surface. It should be remembered, however, that this will not be the case if the soil is wet, and if this is true the subsoil must in some way be underdrained. If the material is clay instead of loam, gravel to a depth of six inches will be necessary. Under any circumstances the gravel should be thick enough to prevent the traffic from forcing it into the clay below, and at the same time prevent the surface water from percolating to the soil beneath, saturating it and weakening it.

It is needless to dump the gravel into ruts, mudholes, etc., and look for traffic to consolidate this and produce a superior highway. Drain-

age must be attended to first, last and all the time, or the results will be anything but satisfactory.

Maintenance and repairs.—(1) After a newly constructed gravel road has been thrown open to traffic, it should be carefully watched in order that any defect may be remedied at once. Shallow ruts and depressions should be repaired without delay, or serious damage will be the result. In repairing a new road the gravel on the sides of the depression may be raked back in place; but after a time it will be necessary to fill the depression with new material. In the latter case the old hardened surface should be slightly loosened with rakes in order to get a bond between the old and new material. The gravel used should be smaller in size and should also contain more binding material than that used in the construction. This material should be stored in piles along the road-side, containing fifteen to twenty cubic yards each. Smaller piles are soon scattered and wasted. (2) Loose stones should be raked off the road surface as soon as they appear. They are uncomfortable for the travelling public, spoil the beauty of the road, and help to destroy it. (3) Care should be taken to fill all the hollows and depressions in the center, made by horses' feet, in order to avoid having water remain on the surface. If the gravel becomes saturated and soft, it wears more rapidly and will soon rut. It is important that the crown of the road should be preserved and that water should not be allowed to run down the center, but should have an unobstructed flow to the side ditches. In cases where the center has been worn hollow the crown should be restored by adding the proper amount of suitable material. This work should be done when the road is wet and soft and the gravel will easily compact and bind together. The ditches and culverts should be kept free from obstructions at all times, to secure an easy flow of water.

Maintenance of this nature may best be accomplished by careful and constant supervision, aided by the use of an ordinary garden rake, to remove the larger pebbles and to smooth the surface. After the road has become compacted such constant attention will not be necessary.

Repairs differ from maintenance in that they are more extensive in character, the surface having to be practically rebuilt. This should be accomplished by the application of one or more layers of gravel,

two inches thick, as a greater thickness does not pack or bind so quickly.

One of the chief advantages of gravel roads, is that they are so easily repaired. Unlike dirt roads, gravel highways may be repaired in the fall without hinderance to traffic or injury to the road. The gravel, except in very extensive and complete repairs, should be applied in patches rather than in great stretches, and then in small quantities as it will more readily combine with the old surface, and at the same time offer less obstructions to traffic. This application may be continued until the entire road has been covered.

The material used for repairs should not be that which is taken from paring down the shoulders or that which has been washed to the sides, but rather new material kept for that particular purpose. Repairs with loam, sand, etc., are bad because such material only serves to put the surface in a sandy or miry condition. The shoulders should always be kept true to the section and the gutters kept open.

For gravel roads, perhaps more than any other, the method of continuous repairs is the most advisable.

Besides the water-worn gravels, there occur along the West Tennessee Valley other vast resources of road material in the form of limestones and cherts which are not discussed above. The Camden chert is famous in West Tennessee and its use as road metal has already been described by the State Geological Survey.*

*Ashley, Geo. H., The Camden chert—an ideal road material, *The Resources of Tennessee*, Vol. 1, No. 2, pp. 34-43.

The Boundary Lines of Tennessee*

By Park Marshall

Introduction—The boundary lines of Tennessee are characterized by unusual irregularities which not only puzzle the people of the State but give rise to frequent inquiries from elsewhere. Some of these irregularities will be explained in the following pages, but as to others there seems to be no solution that is much better than guesswork, or hazy tradition.

There are five distinct deflections in the course of the north boundary that are large enough to be indicated on maps of ordinary size, the first instance being the northward position of the line of Johnson County, and part of Sullivan, in the extreme northeast part of the State. When this part of the line was re-marked the last time (in 1914), the surveyors in running east from Bristol, were surprised to find that the course of the line changes to north 66° 10′ east, which course it follows 8715.6 feet, then runs east to the corner of the State, some 18 miles. Here is an offset something like a mile and a half wide and 18 miles long that is north of the course of the State line as it runs along the rest of the north side of Sullivan County, and the reason for this is not apparent. The east end of this line is eastward and northward from the western termination of the North Carolina line, thus causing the formation of the "triangle" of Virginia territory at that point.

Leaving this portion of the line for the time being, it is best now to follow the boundary in a westerly direction; and, so running, it is found that at the southwest corner of Virginia the line suddenly drops one mile to the south.

Proceeding westward it will be found that at the point where the dividing line between Sumner and Robertson counties, Tennessee, strikes Simpson County, Kentucky, a small V-shaped area of Kentucky is projected southward about a mile.

*The recently issued map of Tennessee by the Geological Survey brings into notice the irregularities of the State boundaries. As few people know how these came about, this article was solicited from Mr. Marshall. It is a matter of regret that it is not practicable to insert a State map. A. H. P.

Again, upon reaching Stewart County, the line changes from nearly west and runs north 5 degrees east for a distance of more than 11,000 feet. This point is 2 or 3 miles east of Cumberland River; there the direction again changes and at first follows a course about north north 85 degrees west, but runs with various changes of direction until it reaches the Tennessee. The area of this offset north of the general course of the State boundary is about 25 square miles.

The boundary west of the Tennessee is definitely fixed as north latitude 36° 30° straight from the Tennessee to the Mississippi, and this is 12½ miles south from where the boundary strikes the east bank of the Tennessee. At the southwestern point of Kentucky, there is a loop in the river in such a form that the Kentuckians therein can not reach any other part of their State unless they travel down the river, or cross it twice, or pass through Tennessee territory.

The eastern boundary, coincident with the boundary of North Carolina, is extremely irregular except along the border of Polk County, and being projected on a map suggests the promontories and bays of a rough and eroded sea coast.

The southern boundary is peculiar in that, according to the most accurate observation, it is not, except at one point, coincident with the 35th parallel as it was intended to be.

The western boundary is the Mississippi River, yet there are several small tracts of land which appear to be cut off by the river, from the states to which they belong. It may as well be stated at once that this is due to changes in the channel of the river. There have been several lawsuits to determine the jurisdiction over such tracts, and the courts hold that the jurisdiction of the State, to which a tract originally belonged, holds good in cases where the river changes its course. It is otherwise in the case of *accretions,* which is the situation where a body of water recedes, or land is formed by deposition.

The northern boundary.—The discussion of the north boundary of the State is naturally considered in two parts: first, the part between Tennessee and Virginia as those states are now constituted, and, secondly, that between Tennessee and Kentucky. It is, in a way, germane to the first of these to give an account of the establishment of the line along North Carolina, inasmuch as the Tennessee-Virginia line was originally meant to be a prolongation thereof.

The reasons and causes of particular deviations in any of the boundaries will not be discussed at great length, as the main purpose is to state how the boundary lines run; the more inquisitive reader is advised to consult the authorities which are referred to.*

It is not necessary to recite the several charters from England before 1665, except to say that on March 24, 1662, Charles II granted a charter to the Lords Proprietors of Carolina, and that on June 30, 1665, he issued a second patent to the same favored courtiers, enlarging the former grant. It is with this that we are mainly concerned. In this grant Charles II confirmed to the Lords Proprietors of Carolina "All that province, territory, or tract of ground * * * * extending north and eastward as far as Carahtuke [Currituck] river, or inlet, upon a straight line to Wyonoke Creek, which lies within or about the degrees of thirty-six and thirty minutes, northern latitude, and so west in a direct line as far as the South Seas."

The controversies which disturbed three states, on the boundary question, were based upon the interpretation of this provision, as well as upon the manner of locating the line, considering the first principles as fixed. The beginning point on Currituck River could not be accurately agreed upon without reference to the given latitude; and when the given latitude is taken it is found to be somewhat indefinite, because the words are that the boundary shall be a "straight westerly line to Wyonoke Creek which lies within, *or about*, 36° 30′". The boundary was to run to the "South Seas". It is well understood that this expression refers to the Pacific Ocean, the distance of which was not known at the time, and which was so

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*The writer has freely used the "History of the South Carolina Cession, and the Northern Boundary of Tennessee", by W. R. Garrett, A.M., (a pamphlet of 32 pages published by the Tennessee Historical Society, 1884. This pamphlet is an excellent production in every way. Prof. Garrett refers to "Byrd's History of the Dividing Line);" "Thomas Jefferson's Works"; "Cooke's History of Virginia"; "Wheeler's History of North Carolina;" "Ramsey's History of South Carolina;" "Marshall's History of Kentucky;" "Haywood's History of Tennessee;" "Ramsey's Annals;" "Ridpath's History of the United States;" "Charters and Constitutions;" Statutes, Journals, etc., of Virginia, Tennessee, North Carolina and Kentucky; manuscript report of Joint Commission of Tennessee and Kentucky, of November 11, 1859. These references contain much interesting and unique matter which the limits of this paper will not permit the present writer to use.

called because the first glimpse of it by the Spaniards at the Isthmus was to the southward.

After the long series of French and Indian conflicts came to a close, the treaty of 1763 fixed the British west boundary at the Mississippi River, which was reaffirmed in the treaty of 1783; and this, of course, controlled in the case of Tennessee.

When the population of the Atlantic seaboard became larger controversies arose between the Crown and Carolina about the boundary, Virginia being a royal province and Carolina a proprietary province. Attempts were made previous to 1710 to fix the boundary, but no agreement could be reached. On March 1, 1710, an order in Council (of the Crown) was made appointing commissioners on the part of Virginia, and under its terms the Carolina proprietors were "to do what on their part does appertain". This joint commission in 1710 and 1711 met with no better success.

In 1727 the governors of Virginia and Carolina came to a tentative agreement to set the compass on the north shore of the mouth of Currituck River or inlet, and to definitely fix the boundary by running a course due west from that point.

This was approved by the King and privy council, and, the proprietors having appointed a commission, a cedar post was placed at the point stated, on March 6, 1728. The place was found to be in latitude 36° 31′ though some parts of the east and west line are as high of 36° 34′ 25.5″.* The variation of the compass was agreed to be 3° west, and a line was run westward with this allowance for variation, which caused "a deviation from true west". The line passes through the Great Dismal Swamp, it being the first time this swamp had been traversed. It reached Peter's Creek, a tributary of Dan River, 241 miles and 30 poles from the coast. This is called the Byrd survey. Colonel William Byrd, of Virginia, certainly one of the ablest Americans of his time, was a member of the commission, and wrote a very readable book, "The History of the Dividing Line", which has already been referred to in a foot note. The Carolina commissioners abandoned the work at 169 miles.

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*Encyclopedia Britannica, "North Carolina". The U. S. Coast and Geodetic Survey finds the starting point on Currituck Inlet to be 36° 33′ 15″.

In 1749 further progress was made, the line being run from Peter's Creek to Steep Rock Creek, 88 miles, making a total of 329 miles from the coast.*

It is clear that it was not understood that the line was to stick rigidly to latitude 36° 30′, but was only meant to approximately follow that latitude; this understanding is important as a partial explanation of the deviations which occurred.

The charter itself is indefinite, for it says the line shall run to Wyonoke Creek "which lies within, *or about,* latitude 36° 30′". Moreover, the provisional agreement between the two governors, approved in the King's Council, fixed the beginning point at what they believed to be 36° 31′; and it provided that the line should change at certain points according to what streams it should strike. One of these was the Blackwater, about 60 miles from the Atlantic, at which the line should turn and run to the mouth of the Nottoway, which caused it there to run south 176 poles. The agreement goes on to say "If a due west line shall be found to pass through islands, or cut out small slips of land, which might much more conveniently be included in the one province or the other, by natural water bounds, in such case the persons appointed for running the line shall have power to settle natural bounds, provided the commissioners on both sides agree thereto".

This gave the commissioners a clear power and discretion to divert the line within reasonable limits. In his book Byrd says that he made concessions to a width of at least a mile, out of consideration for residents who preferred to be placed in North Carolina.

The constant, but slight, deviation northward all the way to the east border of West Tennessee, is understood to be due to errors in astronomical observation and to mistakes in attempted corrections of the compass variation. The method described by Daniel Smith in his diary seems to be fairly correct, but the quadrant used was made by the commissioners and was, no doubt, a rather crude instrument. The compass, at least along the Tennessee part of the line, varied from place to place, and at every observation for latitude it was found that the surveyors were more or less off the line.

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*Peter Jefferson, father of Thomas Jefferson, was a member of this commission. Several prominent men were at different times connected with these boundary surveys, including Wm. Byrd, Gen. Daniel Smith, Gov. John. Sevier, Hon. Felix Grundy, John J. Crittenden, Robert Trimble and Wm. L. Brown. General James Winchester was connected with the south boundary of West Tennessee.

All that can be said then for the northward projection along Johnson and part of Sullivan counties is that no exact reason seems ever to have been given therefor, but that it probably is due to the fact that the land there is of little value and very rough; also the commissioners considered that they had discretion in the matter, and possibly followed Byrd in the way of accommodating the inhabitants.*

There are many other singular deviations not relating to Tennessee, a remarkable one being the north boundary of South Carolina along a course intended to be on the 35th parallel and which consequently would have been a straight line if instructions had been followed. The line wanders north of the parallel to the extent of 17 miles, causing a loss of from 500 to 1000 square miles from North Carolina. Professor Kerr† says, "These lines were run and the latitude observations taken with very imperfect instruments, and the variations of the compass was little understood, so it was not possible to trace a parallel of latitude". He also says, "The northern boundary of the State as run is not only not the parallel of 36° 30′, but is far from coincident with any parallel of latitude, and must be a succession of curves, with their concavities northward and connected at their ends by north and south offsets".

The above remarks are probably true as to the constant drift of the line from the intended course, but can not apply to a case where the line deviates at a startling angle; there is no explanation for this in any published report except in the two instances mentioned in this paper.‡

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*A story of this kind is told: A "contrary" man had settled in that section, who insisted that he had to live in Carolina in order to have any health, and to please him the line was run north of his place. In the vicinity of several of the striking angles there are stories on a par with this. They have a certain value, as they appear to be inventions to explain things that really have no recognized explanation.

†Geology of North Carolina, Vol. 1, p. 2.

‡In the case of Virginia vs. Tennessee, U. S. Supreme Court, 1893, the surveyors thought it necessary to speak specifically about the part of the line just referred to. They took the trouble to examine the country in the direction of the line as it passes Bristol and within the offset, but found no marks; they found, on the other hand, many old marks along the more northerly line as given on our maps.

In 1728 George II appointed the commission on which William Byrd was first named. This commission, in connection with one from North Carolina, ran the line 169 miles to Buzzard Creek, at which point the Carolinas abandoned this work. Colonel Byrd and Wm. Dandridge continued the line 72 miles further, to Peter's Creek, near "Sauratowns"; total, 241 miles 30 poles.

In 1749 Peter Jefferson and Joshua Fry on the part of Virginia, and Daniel Weldon and William Churton on the part of North Carolina, ran the line from Peter's Creek to Steep Rock Creek, 88 miles, a total distance from the coast of 329 miles.

The Southwest Territory, later Tennessee, had not been thought of at this date, the survey stopping at a natural barrier west of which there were no settlers, which barrier was used to delimit the territory which is now Tennessee, ceded by North Carolina forty years later.

By the year 1779 a number of immigrants had come into the country west of the Unaka Mountains and settled both north and south of latitude 36° 30′. It was very important to decide the citizenship of these people, so additional acts were passed for running the line from Steep Rock Creek* (extreme East Tennessee), to the second crossing of the Tennessee River† Virginia appointed Dr. Thomas Walker and Daniel Smith, and North Carolina appointed Col. Richard Henderson and Maj. Wm. B. Smith, to run this line. They met in September, 1779, on Steep Rock, but failed to locate the place where Fry and Jefferson, Weldon and Churton ended their survey in 1749.‡ They agree that they were in latitude 36° 31′ 25″, longitude 81° 12′, and 329 miles from the sea by chain, or 317 miles on a level. They ran south 201½ poles with a view to getting at what they figured to be 36° 30′. There were a number of observations taken and considerable doubt existed as to the exact latitude within limits of a mile or two. A due west line was run about 45 miles to Carter's Valley, and here the dispute became so sharp that the commissions separated, Walker and Smith asserting that the line the commissioners were running was too far north. The Carolina commissioners continued their line westward to Cumberland Mountain, while the Virginia commissioners ran due south two miles, then ran their line both east and west from that point, and ran it westward all the way to Tennessee River, at what is now the northwest

*The writer is not able to identify this creek.

†What is now the eastern, or first crossing, was then called the Holston River.

‡See diary of Gen. Daniel Smith, in possession of Mrs. Horatio Berry, a descendant; also printed in full in the Tennessee Historical Magazine for March, 1915, the print being accompanied by an excellent preface and notes by Dr. St. George L. Sioussat, of Vanderbilt University.

corner of Stewart County, Tennessee. Thus the two lines were about 2 miles apart, the north line from Steep Rock Creek to the Cumberland Mountain being known as the Henderson line, the south line, from Steep Rock Creek to the Tennessee River (said to be about 361 miles), being the Walker line. Walker did not in fact survey the entire distance, but left a gap of what he thought was 109 miles through the mountains, but which in fact was only 97 miles; his guards became tired of the mountainous country, so he made a detour from Clear Creek into Kentucky and took up the survey again when he thought he had reached the proper latitude below on the Cumberland. This gap was supplied by a line run across it in 1821.

Although the Virginians contended for the south line, it has been found that their starting point is in fact in 36° 34′ 53″; also as they progressed their line tended still more to the north until at its termination on Tennessee River it was in latitude 36° 40′ 45″. Just before it reaches the angle in the Stewart County line it is about 36° 37′.

In addition to this the line along Kentucky contains innumerable small angles too minute to show on the map.*

The legislature of Carolina passed a resolution in 1790 adopting the Walker line, but it was non-effective, as the cession to the United States had already been made at the same session. In 1802 commissions of the two states agreed on a compromise and had a line marked out widway between the Walker and the Henderson lines, one mile from each, as far west as Cumberland Gap. It was marked with five hacks in the form of a diamond. This was the "Diamond Line", and it was adopted by the legislatures of both states in 1803, and carried into their codes of laws. Under acts of 1858 commissions re-marked this line in 1859, but their report was not adopted by either State.

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*The Peebles and Cox report of the survey and the re-marking of the line, made in 1859, the calls of which are published in the Act of 1860, (Tenn. Acts), shows many printed pages of calls and needle readings, every call showing a different angle from the preceding one. Nearly all of these angles are very obtuse, and hence as a rule do not affect much territory except in the aggregate. This survey was run east from the Tennessee River in West Tennessee, to the northeast corner of the State, and the rule was to trace, in a backward course, the original surveys, and to run to the old marks if to be found, and where these were not found to accept the reputed line and mark it.

Virginia brought the matter up again in 1870, with a view to getting a new survey and a change of the compromise line of 1803. No action on this was taken by Tennessee until 1872 when the proposition was positively rejected.* During Governor Bate's term, in 1885, a resolution from the legislature of Virginia was received requesting Tennessee to appoint commissioners to join those of Virginia and rerun the line, and providing that, in case Tennessee should refuse, then the Attorney-General of Virginia should bring suit in the U. S. Supreme Court. Governor Bate replied that the question had been settled in 1803; that the claim was stale; and that he did not think it wise to disturb the amity so long existing between the two states.

The same request was made of Gov. R. L. Taylor, and was similarly treated. Virginia then brought suit in the U. S. Supreme Court. In the bill Virginia claimed that the agreement of 1803 was void because it was without the consent of Congress, and also showed that the line was miles further north than had been intended or was justified by the grant of Charles II or by the direction of George II.

This case was decided April 3, 1893, in favor of the Diamond Line claimed by Tennessee, the court holding that this was not such a compact as requires the consent of Congress; that Congress did give an implied consent; that the language "within, *or about,* 36° 30'" justified deviations from that latitude; and that it was competent for states to agree on lines; that they had done so in this case, and to demand a change now is to make a stale claim. Other decrees were made, later, providing for placing stone markers at frequent intervals, and for finding the line of 1803. It was all wound up by 1901.†

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*A committee of the Tennessee legislature made an able report in opposition to the reopenings of the controversy. See Appendix to Journal 1872.

†Supreme Court decree, 148 U. S., p. 503, being Lawyers' Edition, Vol. 37, p. 537:

Decree for markers, U. S. 158, p. 976, L. Ed. 39;

Appointing commissioners, U. S. 177, p. 501, L. Ed. 44, p. 863;

The full report of the surveyor in U. S. 190, p. 63, L. Ed. 47, p. 956.

This case also confirms an agreement between Virginia and Tennessee about the State line along the main street in Bristol. The diamond line ran with the sidewalk on the north side of the street, but it was moved to the center of the street all the way across Bristol, a change of 30 feet. See Acts of Tenn., 1901. This makes it incumbent on Bristol, Va., to pave half of this street.

It has been stated that the Walker line was several miles further north at its beginning than was intended; and trended northward still more; the Henderson line was still further north by 2 miles. A compromise line half way between was made along the Virginia border. Still the Walker line, continued to Tennessee River and at the west border of Middle Tennessee, drifted northward until it was 12½ miles north of 36° 30′.

Kentucky strongly resisted this through the years 1803-1819, the details of which contention are given by Professor Garrett in the paper referred to. She sent her surveyors, Alexander and Munsell, in 1819 and ran a line from the Tennessee to the Mississippi River at 36° 30′.*

The basis of the line was on February 2, 1820, fixed by a treaty between the two states, to which treaty Congress gave its consent. Tennessee was represented by Felix Grundy and William L. Brown, and Kentucky by John J. Crittenden and Robert Trimble. The people east of Tennessee River strongly desired to remain in Tennessee, largely because of their land title papers. The treaty provided that the Alexander and Munsel line and the Walker line should stand as the true lines. Nevertheless there was further dispute in 1831, Kentucky claiming that the Walker line should run straight through southward of the puzzling deviation lying in north Stewart County, Tennessee, and south of Trigg County, Kentucky, but nothing came of this.

Under acts of 1858 by both states, commissioners and surveyors re-ran and re-marked the Alexander and Munsell line from the Mississippi east to the Tennessee, and thence re-ran and re-marked Walker's line to the northeast corner of Tennessee, a distance of about 432 miles, altogether. They started at "Compromise", in 36° 29′ 55.7″, and ran a slightly wobbling line to the Tennessee in 36° 29′ 54″. They then ran down the Tennessee (north) to a point not given, but in fact about 36° 40′ 45″, and ran thence to the northeast corner of the State in 36° 34′ 53.48″, thence about a mile and a half southwest to the North Carolina line at 36° 36′ 0.92″. There was much argument as to the manner of running the line, but it was

*It will be recalled that the Chickasaw treaty ceding West Tennessee and western Kentucky was not made until 1818, hence no titles could be perfected there until that time. So it had not to that time, become necessary to run this part of the line.

finally decided to run to the old Walker marks wherever to be found, and, in all cases where marks could not be found, to run as the Walker line was *reputed* to be. This survey was ratified. A reading of the calls will show that the line is irregular. This is due to the manner of re-running it, and to both errors and concessions that had been made by Walker and Smith. No one seems to know why the Stewart County detour, or the Robertson-Sumner County angle, was made; but the drop of one mile at the southwest corner of Virginia is due to adopting the Walker line instead of the Compromise line of 1802-3.

Strange to say, the Tennessee Constitution states that the north boundary is in latitude 36° 30′, but adds that jurisdiction shall extend to any land acquired by compact, etc.*

The eastern boundary.—The eastern boundary was established by the Act of North Carolina, 1789, ch. 3, ceding to the United States the territory now known as Tennessee. This boundary is described in the act as beginning at the extreme height of Stone Mountain, where the Virginia line intersects; thence along the extreme height to the place where the Watauga River breaks through. It runs along the mountain chain, known by different designations, in a general southwest direction; and finally along the Unaka Mountain to the sourthern border of the State. The greater part of this line was run in 1821. At the northeast corner of what is now Polk County, Tennessee, the commissioners, for some unknown reason, ceased to follow the mountain and ran a due south course to the Georgia line. From the map it would look as if Tennessee was the gainer by this, and North Carolina authorities so consider, but Haywood says the contrary, for it leaves the upper part of the Hiwassee country in North Carolina, "contrary to what was expected".†

There have been a number of disputes along this line, one of which was decided by Turner, Special Judge, in the Supreme Court of Tennessee, in March 1916, on a question of jurisdiction. It is a very carefully prepared and lengthy decision and seems to go over the whole eastern boundary subject. It will soon be published in the State reports.‡

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*The original report is in the Tennessee Archives, and the calls are in "Acts of Tennessee", 1860.

†Haywood, 1891, pp. 27-29.

‡Caroline Lumber Co. vs. McCarthy. It will probably be printed in 6 Thompson (Tennessee).

The main point decided is that the line was designed to run in a general way the main course of the mountains, and is not controlled by the watershed, since as many as five streams break through, carrying water from both sides of the mountains to the eastern limb of Tennessee River.

The southern boundary.—At an early date, the southern boundary of North Carolina was run from a point on the Atlantic northwestward to the thirty-fifth parallel, or at least it was supposed to have been so run; thence to run west. For this reason it was always understood that the 35th parallel was the boundary of Tennessee, Georgia, Alabama, and Mississippi, except that for a time South Carolina claimed a strip 12 to 14 miles wide along the north border of the three last named states. The boundary between Tennessee and Georgia was run under Act of November 10, 1817, of the former, and December 16, 1817, of the latter State. Tennessee was represented by Gen. John Cocke, commissioner, and James S. Gaines, mathematician, while officers for Georgia were Capt. Thomas Stock and J. Camack. Under agreement they met at the Indian village of Nickajack, as near as possible to the lines of the states of Georgia and Tennessee, and the territory of Alabama, on May 15, 1818. They made careful observations and on June 1st placed a durable stone 1 mile and 28 poles south of the center of Nickajack, that point being agreed on as lititude 35°. From that point they ran east to the southwest corner of North Carolina in the same latitude. This line was unanimously agreed to and was at once adopted by both states. It was said to be 109 miles long, though the actual distance is greater.

In 1826 Mr. Camack re-ran this line with better instruments, and found it to be 37.9 chains, (834 yards), south of the parallel, which amounts to over 51½ square miles, or 33,000 acres as compared to the line of 1818. Georgia has expressed dissatisfaction with this line on several occasions, particularly along the borders of Hamilton and Marion counties, Tennessee, where the line seems to vary, and once, (1889), Tennessee passed an act reciting that the line at that point was in doubt. Nothing has been done about it, and the line as fixed in 1818 will undoubtedly stand.* The recent map of the Ten-

*All of these matters are fully discussed by Charles E. Battle, Esq., of Columbus, Ga., in a lengthy paper in Report 19 of the Georgia Bar Association, and reprinted by Franklin Printing & Publishing Co. of Chattanooga. He insists that Georgia can demand that the line be placed at parallel 35°, but in this he is mistaken, for land-marks on agreed lines control. The case of Va. vs. Tenn. settles this. The report and letters are in the Tennessee Archives.

nessee Geological Survey shows the boundary to be southward of the parallel.

The line along Alabama has never been a subject of much contention; only one or two very small areas, where it was lost, having been in controversy on the question of court jurisdiction. The line is continuous with that of Georgia, hence is not at all points on the 35th parallel. Going west it drifts northward and gradually runs to a knife-edge and merges with the parallel for a short distance along the south border of Lawrence County, Tennessee; then crosses the parallel at a very acute angle and so runs until it touches the Tennessee River several hundred yards north of the parallel. There the line runs up the river (south) half a mile, more or less, to the mouth of Bear Creek, and on the west side of the river follows a steady course a few hundred feet south of the parallel. This angle is due to the fact that the West Tennessee observations and survey were not made until many years after the other line was fixed.*

The line along Mississippi, from the Tennessee to Mississippi River, was surveyed, soon after the Chickasaws ceded that country, by Gen. James Winchester.† This line was not believed to be correct by either Tennessee or Mississippi. In 1831 Governor Carroll of Tennessee appointed I. Thompson to locate the 35th parallel, which he did with much care, using a mercurial horizon in making his observations. He found the parallel to be "on the eastern bank of the eastern chute of Island No. 47, known as Cow Island" (of Mississippi River), a point nearly five miles south of the survey that had been made by General Winchester in 1819. This line, however, was not the one finally adopted, though very near it. Governor Brandon of Mississippi sent a message to the legislature in 1829, contending that the Winchester line was too far south. Why he assumed this view is not known, but he raised the question rather vigorously. It was claimed that Memphis was in Mississippi. After Thompson's

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*The Alabama-Tennessee line was run and marked by General Coffee, Surveyor-General, in 1818. The boundary crosses the 35th parallel at the middle of the south boundary of Lawrence County, east of which point the boundary is south of the parallel, and west it is north of it. There is not much loss to either State.

†See article on Gen. Winchester in Tennessee Historical Magazine for September, 1915. Gen. Winchester was appointed by President Monroe in 1819 to run this line on latitude 35°, being the Chickasaw boundary.

observations were made, in 1831, Mississippi was in favor of dropping the subject, and asserted that the Thompson survey was wholly *ex parte,* therefore not binding. Under authority of acts passed by both states a new survey of the Mississippi-Tennessee line was made in the year 1837. The commission making the survey was composed of B. S. Ludlow, Surveyor of Public Lands; D. W. Conolly and W. Pietrie on the part of Mississippi; and J. D. Graham and Austin Miller on the part of Tennessee. The result was a line commencing on the Tennessee River "six four-pole chains south, or above, the mouth of yellow creek, and about three-quarters of a mile north of the line known as "Thompson's line * * * * and terminating on the east bank of Mississippi River (opposite Cow Island), 16 chains north of Thompson's line. This line was agreed to by both states. It gives Tennessee 200 square miles more than did the Winchester line. After all this the recent government surveys show that this line is something like half a mile south of the latitude they were trying to find.*

In his report in 1819 Thompson uses an argument to explain in part the errors made by Winchester and others. He says that every survey is made on a great circle, and if not corrected in this respect, would on a long line amount to a considerable error. It would seem, however, that an error due to this cause would carry the line to the southward, not to the northward, of the desired course.†

The western boundary—There is not much to be said about the western boundary more than has been said in the first part of this paper. As before stated the treaty of 1763 fixed the west boundary of the British colonies at Mississippi River. This has been held to mean the middle of the channel as the channel ran at the time of the treaty, or as it ran at the most remote period since that time of which we have proof. These questions are discussed in the case of W. D. Alexander vs. W. F. Woodruff, decided by the Tennessee Supreme Court at Jackson, Tenn., in 1910.

As a net result of the manner of running the boundary lines of the State, Tennessee gained about 2,500 square miles of territory over what it would have had under surveys accurately following the rules laid down. This did not in any case arise from design. Indeed the

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*See Acts of Tennessee 1837-8. Also see Encyclopædia of Mississippi, Vol. I.

†The papers are in the Tennessee Archives.

lines adopted were, generally, not the lines run by the commissioners and surveyors on the part of Tennessee.*

*Professor Garrett's article on "The South Carolina Cession," (which has been referred to in a foot note), really has no bearing on the boundary of Tennessee, as the strip once claimed by South Carolina is south of the recognized boundary of Tennessee. The "Boundaries of the United States", issued by the U. S. Geological Survey, 1904, being Bulletin 226, Series F, Geography, 37, may be here referred to, although its citations are not complete.

The Glenmary Oil Field

By A. H. Purdue

Since the last issue of the *Resources,* the Glenmary field has produced its second well. This is known as the Todd well and is located less than a mile north of the town, a half mile east of the Cincinnati, New Orleans and Texas Pacific R. R., and just north of Black Wolf Creek. It perhaps is a mile east of Pemberton well No. 1 described by Dr. L. C. Glenn in Vol. VII, No. 1, of the *Resources.* It was begun October 30, 1916, and completed January 25, 1917.*

Lack of cars for shipping is said to have prevented continued pumping for sufficient time to test the strength of this well. The last day it was pumped, it is reported to have produced 105 barrels. The capacity previous to that time was not learned. It is also reported that after the last day's pumping, the shale below the casing caved in and shut off the flow. At the time of the writer's visit, this shale had not been cleaned out. When the well was first brought in, there was an escape of gas that blew oil above the top of the derrick.

The elevation of the mouth of the Todd well, according to Mr. R. A. Shiflett, Chief Mine Inspector of Tennessee, is 1255 feet (aneroid). That of the Pemberton well is given by Dr. Glenn as 1248 feet. The oil is reported by Mr. Shiflett as coming from sand containing small pebbles, just as in the Pemberton well, the sand of both being in the St. Louis limestone. The Todd well is 1249 feet deep; the Pemberton well, 1244 feet.

The contractors for both wells were the same parties (Sackrider and Fuller) and according to their records the top of the St. Louis (Newman) limestone in the Pemberton well was struck at 950 feet; in the Todd well, at 1045 feet. Reducing the mouths of both wells to the same level, this makes an apparent difference in the elevation of the top of the St. Louis at the two wells of 87 feet. This difference may in part be accounted for in the general rise of the rocks to

*The drillers report that there were many mishaps; that with good luck the well could have been drilled in about 28 days.

the west, which according to Dr. Glenn is between 30 and 40 feet per mile, in the vicinity of Glenmary.*

According to a log of the Todd well, furnished the writer by Mr. R. A. Shiflett, the sequence of rocks above the St. Louis limestone in the two wells does not agree, but below the top of the St. Louis, they are in general the same, as shown by the following section:

Sections of Pemberton and Todd wells, below the top of the St. Louis limestone

Pemberton well†		Todd well
St. Louis limestone.....	98 ft.	25 ft.....St. Louis limestone
White slate	3 ft.	8 ft.....Slate
Dark lime	93 ft.	42 ft.....Black lime
Black slate	3 ft.	3 ft.....Black slate
Gray sand	8 ft.	
Hard white lime.....	77 ft.	96 ft.....White lime
Gray sand and small pebbles, oil	8 ft.	11 ft.....Oil sand, small pebbles
Hard white lime	4 ft.	19 ft.....Lime

It will be seen that the distance from the top of the St. Louis limestone to the oil "sand" in the Pemberton well is 282 feet. In the Todd well, the distance is 174 feet. From the comparison, made easy by the table, it appears that this difference is due to the varying thickness of the beds penetrated. Should such variation be typical of the St. Louis formation in this locality, the depth of the oil-bearing layer below its top will of course be everywhere uncertain.

Subsequent to the publication of the article by Dr. Glenn on the Pemberton well, it was drilled 40 feet deeper, making the total depth 1284 feet. It is reported that in this increased depth the drill went through 28 feet of pebbly sand, and that the well now pumps 7½ barrels a day.

The oil men who are familiar with the geology of the Irvine and Scottsville fields of Kentucky very naturally ask the question "What is the chance for oil below the Chattanooga shale in the Glenmary field " To this question the geologist can only reply that the source of the oil in the Kentucky fields mentioned is almost certainly the Chattanooga shale. The Chattanooga shale is everywhere quite uniform in nature. These things being true, oil can reasonably be

*Res. of Tenn., Vol. VII, No. 1, p. 42, 1917.

†Res. of Tenn., *Loc. cit.*

expected either just above or just below this shale, provided that at these levels there are open rocks to serve as reservoirs; provided also that the open rock above the shale is itself covered by another bed of shale or some other "tight" rock; and provided again, that the structure is suited to oil accumulation.

So far as the writer is informed, no oil has been secured from the horizon immediately above the Chattanooga shale, and this fact reduces the hope of striking it at that level in the Cumberland Plateau.

There may be a bed of sand beneath the Chattanooga shale in parts of Cumberland Plateau, as there is in the Western Highland Rim of Tennessee, but it has not been observed in the outcrops along the eastern escarpment of Cumberland Plateau, nor is it indicated in the available well records. In Toomey Nell No. 1, 4 miles northwest of Oneida, Scott County, the Chattanooga shale is followed by a limestone* and the same order of occurrence would be expected at Glenmary, though with our present want of knowledge of the extent of these beds, this can not be relied upon.

The beds mentioned probably are of Silurian age, and disappear somewhere east of the west escarpment of the Cumberland Plateau, for they are wanting there. However, the rocks below those of Silurian age in Cumberland Plateau are also mainly limestone, so in any case limestone is the probable rock beneath the Chattanooga shale; and inasmuch as this is true, oil if struck, probably would come from fissures.

The question of the depth of the Chattanooga shale in the Glenmary field is also a practical one. In Toomey well No. 1, Oneida field, above referred to, the top of the St. Louis (Newman) limestone, was struck at 750 feet. The base of the Chattanooga shale was reached at 1540 feet, making the distance from the top of the St. Louis to the base of the Chattanooga 790 feet. According to this, the base of the Chattanooga shale in the Pemberton well would be reached at 1740 feet, and in the Todd well at 1835 feet. But again, these figures cannot be relied upon except as a general indication of what may be expected, for the thickness of the St. Louis limestone and the underlying Ft. Payne chert probably varies from place to place.

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*Res. of Tenn., Vol. V, No. 4, p. 176, 1915.

It is understood that if oil is sought in association with the Chattanooga shale, drilling should not cease until the limestone beneath it has been penetrated for some feet. If oil is not then struck, the well should be shot before it is abandoned.

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Marketing Woodlot Products in Tennessee ..... W. D. Sterrett

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Marketing Woodlot Products in Tennessee

BY W. D. STERRETT

Forest Examiner, U. S. Forest Service *

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THE WOODLOT SITUATION IN TENNESSEE

A permanent woodlot is an essential part of a well equipped farm. In heavily wooded states like Tennessee,† however, farmers are likely to overlook this fact and recklessly cut, misuse, or clear up their forest areas.

The reduction in woodlot area which is continually going on might often profitably be held in check. It is always possible to hold timber crops for more favorable market conditions. As a rule it is advisable to allow thrifty immature timber to mature, rather than to remove it at a total loss; and it is often better to practice intensive agriculture on areas already cleared than to clear additional areas which are in growing timber. Farmers who give a little consideration to the direct and indirect advantages of having a woodlot on the farm will generally see the importance of keeping certain areas permanently in timber and of handling these permanent woodlots so as to increase their productivity and value.

The one direct economic reason for the use of land as woodlot is that on some areas timber is the most profitable crop which can be grown. This, of course, is especially true of poor and rough land, such as is found mostly in the mountainous sections of the State.

Most frequently, woodlot occupation of farm land can be justified only by indirect economic considerations because the land is usually adaptable to more valuable crops; and for this reason the woodland should form but a small part of the total farm area. The important indirect reasons, a number of which are active in any particular case, are: (1) for convenience of home use for fuel, posts, and

†In 1910, 40 per cent of the total farm area of the State was in woodland. No county in the State has less than 20 per cent of its farm area in woodland, while in some of the mountain counties over 70 per cent of it was wooded. (See map.)

other farm needs; (2) as a windbreak for buildings or crops; (3) as a shelter for stock; (4) for protection of land from erosion; (5) as a temporary, soil-renewing crop on worn out land; (6) as furnishing work for man and teams during spare time; (7) for purely esthetic reasons and for recreation purposes, for which reasons alone a farm with a well-located grove of trees, however small, will sell for more than one without; (8) as a temporary crop on intrinsically good agricultural land, which it is wished to hold for future clearing and development.

Fig. 1.—Woodlot kept as a windbreak and wood supply. Lawrence County.

Determination of location and size of woodlots should be largely influenced by the above considerations, and especially by the relative value of particular parcels of land for agricultural as compared with forest crops.

The chief obstacles to proper consideration by the farmer of the economic possibilities of a woodlot on his farm are his lack of knowledge: (1) of the market possibilities for various woodlot products and of how to market them; and (2) of the rate of growth of and possible yields per acre from properly cared for stands of different species and ages. This article is intended to give the farmer in

Tennessee information in regard to marketing; and it is hoped that by showing him how he can most profitably dispose of forest products which he already has on hand his interest in the possibilities of permanent woodlots may be aroused.

Woodlot products resulting from clearing of land for agriculture are being wasted in large quantities every year, not only because of lack of immediate local demand, but also because of lack of knowledge of values, specifications, and possible markets for different classes of materials. Information on marketing will help the farmer to dispose of such material at a profit.

WOODLOT REGIONS

The character of the woodlots in the six natural regions (see map) into which Tennessee is divided varies considerably. The kinds and quality of timber trees and the size and economic usefulness of the woodlots are very different in different parts of the State, as are also the markets which are available for the sale of woodlot products.

The Unaka Mountain Region and the Cumberland Region have only about one-third of their area in farms; and nearly two-thirds of the farm land is forested. Heretofore, the timber industry has been all important, the rough physiography, the large proportion of thin soils, and the shortness of the growing season having retarded agricultural development. There are no large towns or cities and no great variety of wood-using industries, transportation is deficient, and the supply of timber is abundant, so that the market for woodlot products is poor. Nevertheless, permanent woodlots should be retained on a large portion (probably one-half) of the forested farm land, either because the land is too poor or rough for agriculture or because the forest cover is needed as a protection against erosion.

Lying between the Unaka and Cumberland Mountains is the valley of East Tennessee. Eighty-five per cent of the total area is in farms, and thirty-seven per cent of the farm area is woodland. This is a prosperous agricultural and manufacturing region, with two large cities (Chattanooga and Knoxville) and a number of small cities and large towns. There are, accordingly, good markets for forest products. Transportation facilities are fair. At least half of the area at present in farm woodlots should remain forested, either because the rough, steep land is chiefly valuable for timber growing or because the forest is needed for protective purposes.

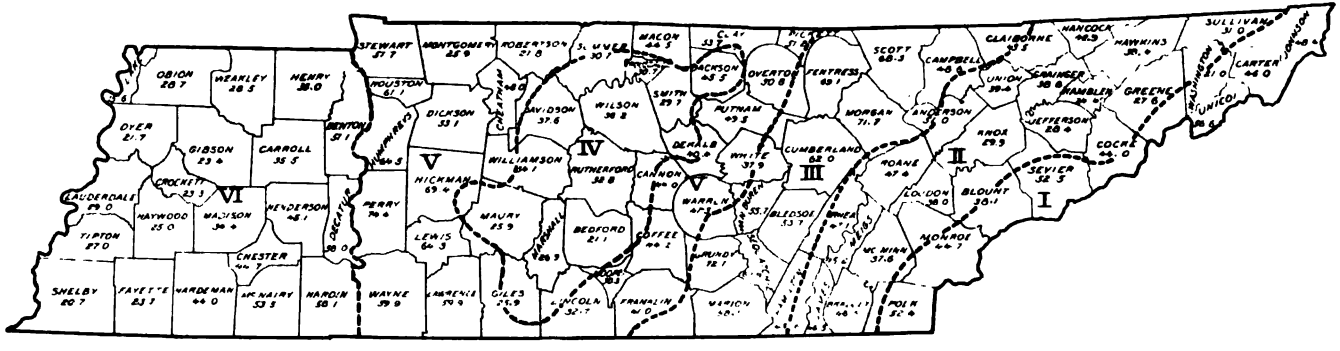

Fig. 2.—Farm woodlot regions in Tennessee. The figures show per cent of woodland on the farms in each county in the State.

I. Unaka Region
II. Valley of East Tennessee
III. Cumberland Plateau
IV. Central Basin
V. Highland Rim
VI. West Tennessee Plateau and Bottom Lands

The Highland Rim is a broad shelf-like region surrounding the Central Basin. It is less developed, as a whole, than the valley of East Tennessee, and has 47 per cent of its farm area still in woodland. Seventy-four per cent of the area of the region is in farms, and most of the remainder is in comparatively small, isolated timber tracts; about one-fourth of the area is steep and rough, and not well suited to agriculture. The remaining three-quarters lies well and has large agricultural possibilities at present little developed. Probably one-third of the total farm area should be permanently held in woodlots. There are no large cities in the region; but it is, as a whole, easily accessible to Nashville. There are also a number of large towns, so that local market conditions for forest products are fair. Transportation facilities, however, are often very poor.

The Central Basin is a limestone region and is the richest and most prosperous part of the State, with the highest average value per acre of farm land, the lowest proportion of its farm area in woodland, and the highest proportion of its total area in farms. The small proportion of woodland and the presence of the large city of Nashville and a number of small cities and large towns, make the market for forest products excellent. Transportation facilities are usually good. About one-quarter of the land is steep and rough, but on account of the limestone formation will usually grow blue grass for pasture. Over half of this rough land, however, should be permanently held in woodlot for protective and other purposes.

The West Tennessee Region is the largest of the six, and amounts to one-quarter of the total area of the State. Thirty-five per cent of its farm area is in woodland, and 85 per cent of its total area is in farms. There are scattered timber tracts, chiefly in undrained bottom lands of the Mississippi and Tennessee rivers and their tributaries; but most of this land will finally be drained and become available for agriculture. There is comparatively little rough, steep land; and most of the land has good agricultural possibilities which are but little developed, so that not over half of the present area in forest should remain in permanent woodlots. The city of Memphis, located in the southwestern corner, and a number of large towns scattered over the region furnish very fair markets for forest products. Transportation facilities by rail or by water are usually good.

TABLE 1.—*Commercial trees in the different woodlot regions in Tennessee, arranged in order of their relative importance as indicated by the proportion which each formed of the total lumber cut of all species in the region in* 1912.

Entire State		I Unaka Mountain Region		II Valley of East Tennessee		III Cumberland Region	
Species	Per cent of total lbr. cut	Species	Per cent of total lbr. cut	Species	Per cent of total lbr. cut	Species	Per cent of total lbr. cut
Oak	40.6	Yellow Pine	25.5	Oak	46.3	Oak	39.5
Poplar	11.5	Oak	19.5	Yellow pine	21.8	Poplar	18.6
Yellow pine	10.1	Hemlock	14.1	Poplar	13.6	Yellow pine	16.3
Red gum	7.5	Poplar	9.9	Chestnut	4.2	Chestnut	7.4
Chestnut	5.0	Chestnut	9.7	White pine	3.7	Cedar	4.0
				Hemlock	3.5		
				Cedar	1.6		
Hickory	4.5	White pine	8.5	Hickory	1.2	White pine	3.6
Cedar	3.4	Maple	4.5	Red gum	.8	Hemlock	3.0
Hemlock	3.3	Spruce	1.8	Walnut	.8	Hickory	2.5
White pine	2.5	Basswood	1.7	Maple	.7	Basswood	1.9
Ash	2.0	Buckeye	1.5	Basswood	.5	Ash	.7
Maple	1.6	Ash	1.0	Beech	.4	Buckeye	.7
Beech	1.3	Birch	.7	Ash	.4	Beech	.5
Cypress	1.1	Beech	.3	Buckeye	.2	Maple	.5
Basswood	1.0	Hickory	.3	Birch	.1	Walnut	.4
Cottonwood	1.0	Bellwood	.3	Sycamore	.1	Cherry	.2
Sycamore	.7	Cherry	.2	Elm	.1		
Elm	.7	Walnut	.1				
Tupelo	.5						
Buckeye	.5						
Walnut	.4						
Spruce	.3						
Birch	.2						
Cherry	.1						
Persimmon	.1						
Dogwood	.1						
Bellwood	*						
Others (Hackberry, sassafras, mulberry, butternut)—locust	*						

*Less than one-twentieth of one per cent.

TABLE 1.—*Concluded.*

IV Central Basin		V Highland Rim		VI West Tennessee	
Species	Per cent of total lbr. cut	Species	Per cent of total lbr. cut	Species	Per cent of total lbr. cut
Oak	32.3	Oak	54.4	Oak	42.2
Cedar	28.2	Poplar	14.6	Red gum	26.3
Poplar	13.4	Hickory	9.6	Poplar	5.3
Hickory	7.9	Chestnut	8.2	Hickory	5.3
Chestnut	4.2	Beech	2.5	Ash	4.7
Beech	4.2	Tupelo	1.6	Cypress	4.2
Ash	2.7	Red gum	1.3	Cottonwood	3.4
Basswood	1.5	Ash	1.1	Sycamore	2.2
Elm	1.5	Maple	1.0	Maple	1.8
Red gum	.9	Basswood	.9	Elm	1.5
Walnut	.8	Elm	.7	Tupelo	.8
Sycamore	.7	Walnut	.6	Yellow pine	.5
Maple	.6	Buckeye	.6	Dogwood	.3
Buckeye	.4	Cedar	.4	Persimmon	.2
		Sycamore	.3	Beech	.1
		Cottonwood	.3	Walnut	.1
		Persimmon	.3	Birch	.1
		Dogwood	.2		
		Cherry	.1		

NATIVE TREE SPECIES

The seven most important commercial trees on farm woodlots in Tennessee are, in order of their importance, oak, poplar, hickory, cedar, chestnut, sweet gum, and yellow pine. (See also Table 1.) From these seven trees is cut over four-fifths of the lumber produced annually in the State. Oak is the most important of all and enters all mixtures and types, while the others are often absent. Oak and poplar are important throughout the State. Hickory is important everywhere except in the Unaka Mountain Region. Cedar has its chief importance in the Central Basin Region where it ranks next to oak in the amount cut into lumber. It also has some importance in the Highland Rim, the Cumberland, and the Valley of East Tennessee regions. Chestnut is important east of the Tennessee River but of no importance in West Tennessee. Much more of it is found on and cut from rough timber tracts than farmers' woodlots. Yellow pine (shortleaf) is important only in the eastern half, and red (or sweet) gum only in the western half of the State. Most of the yellow pine cut in the State is from large timber tracts in the mountains.

Of secondary importance on farm woodlots are the valuable woods, walnut, cherry, and ash, and the less valuable woods, basswood, elm, maple, sycamore, buckeye, beech, and black gum. Ash, maple, beech, black gum, walnut, and cherry are rather widely distributed over the State; basswood and buckeye occur commercially only east of the Tennessee River; sycamore and elm occur everywhere except in the mountain regions. Trees usually too small for lumber but of considerable value and occurring in small quantities in woodlots are black locust, dogwood, and persimmon, all of which have a wide distribution throughout the State. Hemlock, white pine, spruce, cypress, and tupelo gum seldom occur on farm woodlots and for this reason are not considered in this report.

USES OF NATIVE WOODLOT TREES

The market in which woodlot material may be sold depends upon both the species of the wood and the product that is to be derived from it. Furthermore, certain industries use logs, bolts, and billets; while others require lumber for their raw material. Those which use logs, bolts, and billets are of most importance to the farmer because he is seldom prepared to turn out sawed lumber.

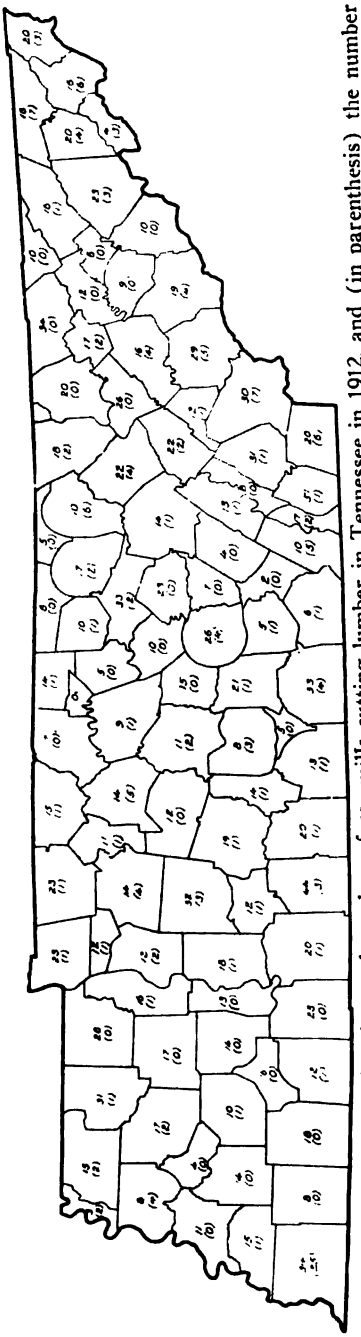

Fig. 3—Showing by counties the total number of sawmills cutting lumber in Tennessee in 1912, and (in parenthesis) the number of mills cutting over 1,000,000 board feet.

1. Markets According to Product

Lumber.—About one-half of the lumber manufactured in Tennessee in 1912 (932,572,000)* was cut from woodlot timber. All species were used. The importance of the various native woodlot tress in the lumber industry is shown for each of the natural regions of the State in Table 1.

Other products made directly from logs, bolts, and billets.—The industries using logs, bolts, and billets, and the approximate amount of raw material consumed by each are shown in Table 2. The remarks in the table on the kinds of material used and the proportion cut from farmers' woodlots are intended to give an idea of the possibilities of a particular industry as a market for woodlot products. Bolts are short round logs six feet or less in length, usually with bark left on, but sometimes peeled as in the case of pulp bolts. Billets are short pieces of rived stock, less than four feet in length; such as rived spoke stock, rim stock, whiffletree stock, tight stave and heading stock, which have been roughly hewed into the form in which they are to be finally used. At points remote from the market material in the form of billets can often be gotten out at a profit where the cost of transporting logs or bolts would be too great.

Firewood forms nearly half the total volume of woodlot products, but it has little or no stumpage value. Where coal is cheap, more cut wood, suitable for burning, is left in the woods, than is used, and the farmer's problem is to decrease the proportion which is left to rot.

About 90 per cent of all the wood taken from woodlots, except that which goes into firewood, is used for saw and veneer logs, railroad ties, and material for use on the farm. Trees of good size and quality are usually cut into saw logs; small and medium sized trees and the rough tops of larger ones yield ties, two-thirds of which are hewed. White oak, chestnut oak, and post oak ties may be sold for nearly twice as much as red oak, black oak, and chestnut ties, and more than twice as much as softwood ties. Since the cost of hauling to the railroad or river cuts down the profit more than anything else, a one trip a day haul can be made profitably only with ties of the first three species mentioned.

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*See Table 2.

TABLE 2.—*Wood-using industries in Tennessee (classified according to their products) using logs, bolts, and billets, and the approximate amount of raw material consumed by each.*

Product	Number of board feet, or its equivalent, used	Remarks
1. Rough lumber	932,572,000[1]	All species used. About half cut from farmers' woodlots.
2. Firewood	4,730,524[2] (cords) in 1908	Mostly cut and used on farms.
3. Ties	150,000,000[3]	75 per cent white oak, including chestnut oak and post oak; 20 per cent red and black oaks; 5 per cent others.
4. Tight cooperage	150,000,000[4]	White oak, from choice logs and bolts. Over half from farmers' woodlots.
5. Fence posts, rails, and hewed pieces used on farm	100,000,000[5]	Chiefly cedar, locust, chestnut, and oak. Mainly from farmers' woodlots.
6. Slack cooperage	75,000,000[4]	All species. About half from farmers' woodlots. Medium to small trees.
7. Wheel parts (spokes and rims)	40,000,000[3]	Hickory, white oak, and red oak. All choice logs down to 10 inches in diameter.
8. Veneer	30,000,000[4]	All species. Choice and common logs—variable requirements.
9. Extract wood and bark		
Chestnut wood	(50,000 cords)[4]	
Oak bark	(25,000 cords)[4]	
10. Handles	15,000,000[3]	Chiefly hickory, some white oak and ash. Mainly from farmers' woodlots.
11. Poles and piles	10,000,000[5]	Cedar and chestnut, for poles; miscellaneous species for piling; largely from farmers' woodlots.
12. Pulpwood	10,000,000[4]	Mostly poplar; some red and black gum; half from farmers' woodlots.
13. Mine timbers (not including sawed lumber used)	8,000,000[5]	Chiefly oak. Very little from farmers's woodlots.
14. Shuttle stock	5,000,000	Dogwood and persimmon. Mostly from farmers' woodlots.
15. Pump rods and boat oars	3,000,000[3]	Ash and hickory. Choice logs, medium to large in size. About half from farmers' woodlots.
16. Sporting goods stock	3,000,000[3]	Hickory and ash. Choice second-growth, small to medium size. Half from farmers' woodlots.
17. Excelsior	2,000,000[3]	Poplar, pine, cottonwood, and willow. One-half from farmers' woodlots.
18. Butchers' blocks and skewers	1,500,000[3]	Hickory.
19. Turned porch columns	500,000[5]	Poplar—small, clear sap logs.

[1]1912 Census returns. [2]1911 Census returns. [4]1911 Census returns.
[3]According to estimate in Circular 181 of the Forest Service. (1910.) [5]Special investigation by the Forest Service. [5]Estimate by the author.

Good markets for certain classes of woodlot materials are furnished by the tight cooperage, vehicle, and handle industries. Supplying the bolts and rived stock for these markets often gives opportunity for the employment of farm labor during lax periods. The tight cooperage stock industry is confined chiefly to rough and inaccessible parts of the Cumberland, Highland Rim, and West Tennessee regions; but the vehicle stock and handle industries are more generally distributed throughout the State. White oak alone is used for standard heading stock for spirituous liquors. This brings a much higher price than does oil barrel stock, which is made also from chestnut oak and red oak. Large trees are required for tight

Fig 4.—Chestnut wood and chestnut oak bark at the tannic acid or extract plant. Elizabethton.

cooperage; and, since only a small part of the tree can be used, there is much waste unless the remainder of the tree is used for some other purpose. Vehicle and handle stock comes chiefly from small and medium sized hickory, white oak, red oak, and ash trees of good quality.

Mining timbers are of some importance as a woodlot product for farmers in a number of counties in the Cumberland region, although

these are mostly taken from large timber tracts owned by coal operators.

The tanning industry furnishes a fair market for chestnut oak bark and hemlock bark in the eastern half of the State, wherever these species occur in any quantity. At present, however, it pays in most cases to take the bark only from comparatively large trees, 15 or 20 inches in diameter. There is a market for chestnut wood for tannic extract plants throughout its range in the State.

The market for chestnut and cedar poles is good throughout the State. That for cypress, oak, and gum piling for shipping purposes is good in the extreme western part of the State near the railroad, and occasionally a local market can be found.

Products made from lumber.—Of the total lumber cut in Tennessee, about one-third goes into various wood-using industries in the State. A directory of the largest consumers of lumber in these various industries will be found on page 178. It will sometimes be possible to get more for lumber by selling it direct to these wood-using industries than by selling it to the local lumber trade or to general dealers and shippers. The following are the products made from sawed lumber arranged in order of the amount of lumber used. The principal kinds of native woods used for each are also shown.

1. Planing mill products—all kinds and grades of lumber.
2. Boxes and crates—chiefly cottonwood, gum, poplar, and pine.
3. Furniture—chiefly oak, gum, and poplar, of all grades.
4. Sash, doors, and blinds and general mill work—chiefly pine, oak, poplar, and chestnut of good grades.
5. Car construction—pine and oak.
6. Vehicle construction—select hickory and white oak dimension stock, and wide boards of poplar and gum of good grade.
7. Caskets and coffins—pine (yellow and white), chestnut, and poplar of medium grade.
8. Chairs—low-grade oak lumber.
9. Trunks and valises—poplar, pine, basswood, chestnut, and buckeye, of medium grades.
10. Agricultural implements—oak, poplar, and pine of good grade.
11. Refrigerators and kitchen cabinets—oak, poplar, and pine, chiefly of the lower grades.
12. Curtain poles—chestnut, poplar, oak, pine, beech, medium grade.

Fig. 5.—Mature white oak worth about $25 standing.

2. Markets According to Species

The oaks.—The oaks are by far the most important of the native woodlot trees, since they are found in all kinds of woodlots throughout the State. From the standpoint of utilization two general kinds are recognized: (1) white oak (including white oak, post oak, chestnut or rock oak, bur oak, cow or basket oak, and swamp white oak); and (2) red oak (including red oak, black or yellow oak, scarlet or spotted oak, pin oak, Spanish or southern red oak, water oak, shingle oak, willow oak, and black jack oak). White oak is more

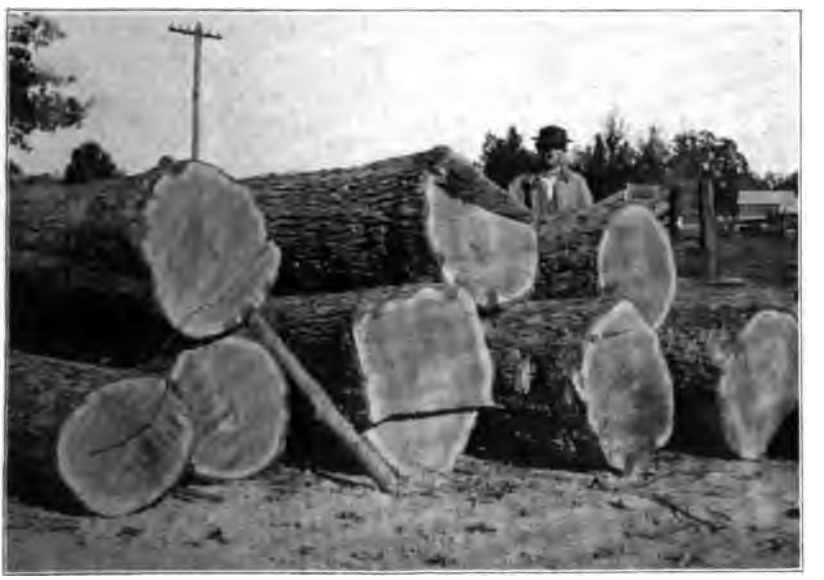

Fig. 6.—White oak for quarter-sawed and veneer stock for Memphis mills.

valuable than red because it is stronger, tougher, more durable, and therefore adapted to a greater number of uses. White oak trunks are usually more clear of branches and less apt to be defective than those of red oak. For certain uses not requiring durability, red oak often brings the same price as white. White oak is more valuable in small sizes for ties, spokes, tight staves, vehicle dimension stock, and handles; and smaller trees of white than of red oak can thus be utilized. Red oak lumber is often discriminated against in the market as not being so strong as white oak, which is not uniformly true.

1. *White oak.*—The important uses to consider in marketing white oaks are: saw and veneer logs, ties, vehicle stock, and logs and bolts for tight and slack cooperage and handles. For clear or practically clear logs 18 inches and over in diameter at the top end, the most profitable markets are sawmills and veneer mills. Such logs always bring good prices at large plants which specialize in them. Clear logs less than 18 inches top diameter are most profitably sold to local mills manufacturing vehicle stock, tight cooperage, or handles; or they may be cut up on the farm into rough billets, according to specifications furnished by the prospective buyers, and shipped to the mills in that form. Large logs of lower grade will pay best if sold to sawmills, provided two hauls a day per team can be made to the mill, shipping point or river; otherwise they should either be sold to small local mills or cut into ties. Small "common" and large "cull" or low grade logs may best be disposed of to local mills, hewed into ties, or cut into bolts and sold to slack cooperage plants.

A summary (based on prices existing in 1914) *showing what different classes of white oak material should be worth when delivered on cars, at the river, or at local mills*

Large select saw and veneer logs	
28 inches and up in diameter at top end	$30 to $50 per 1,000 bd. ft.
24 to 28 inches	$20 to $30 per 1,000 bd. ft.
18 to 24 inches	$15 to $25 per 1,000 bd. ft.
Large common logs, 1-3 off above prices	
Small clear and common saw logs	$12 to $20 per 1,000 bd. ft.
Cull saw logs	$ 5 to $10 per 1,000 bd. ft.
22-inch (length) heading bolts clear,	
8 to 20 inches in diameter	$15 to $20 per 1,000 bd. ft.
35-inch (length) stave bolts, clear	
8 to 20 inches diameter	$15 to $20 per 1,000 bd. ft.
24-inch (length) rim bolts, clear,	
8 to 20 inches in diameter	$15 to $20 per 1,000 bd. ft.
28-inch (length) spoke bolts, clear,	
8 to 20 inches diameter	$15 to $25 per 1,000 bd. ft.
40-inch (length) handle bolts, 6 inches and up	$ 8 to $14 per 1,000 bd. ft.
Railroad ties, (6″x8″x8′; 7″x8½″ to 9″x8½′)	$12 to $15 per 1,000 bd. ft.
Slack cooperage bolts, 3 to 6 feet in length	$ 5 to $10 per 1,000 bd. ft.
Chestnut oak* bark	$ 8 to $10 per cord

(1,000 feet of saw logs will yield from half a cord to a cord of bark.)

*Chestnut oak seldom produces select logs, but it is the only oak whose bark is valuable for tanning material. Otherwise it is not different from white oak in its utilization.

2. *Red oak.*—Large, clear, red oak logs should go to saw and veneer mills; medium sized and small clear logs and bolts should go into rim stock (usually sawed), spoke stock (both sawed and rived), and oil barrel staves and heading; common and cull logs should usually be sold to local sawmills or slack cooperage plants, or should be hewed into ties.

Fig. 7.—Oak bolts for tight barrel staves, worth $7 to $9 per cord. Dresden, Weakley County.

A summary (based on prices existing in 1914) *of the values of different classes of red oak material delivered f. o. b. cars, or on water, or to local mills*

Large select saw and veneer logs	
28 inches and up in diameter	$25 to $40 per 1,000 bd. ft.
24 to 28 inches in diameter	$20 to $25 per 1,000 bd. ft.
18 to 24 inches in diameter	$15 to $20 per 1,000 bd. ft.
Large common logs 1-3 off of above prices	
Small saw logs of all grades	$ 5 to $15 per 1,000 bd. ft.
22-inch oil heading bolts 24-inch rim bolts 36-inch oil stave bolts 20 to 30-inch wagon and auto spoke bolts	$10 to $15 per 1,000 bd. ft.
Slack cooperage bolts	$ 4 to $ 8 per 1,000 bd. ft.
Railroad ties, finished (where there is a market)	$ 7 to $10 per 1,000 bd. ft.

Fig. 8.—Large, clear red oak, suitable for veneer logs.

Poplar.—The leading use of yellow poplar is for saw and veneer logs. Poplar saw logs will always net more money than oak logs of similar size and quality because they are much lighter and cheaper to handle and transport. Furthermore, poplar logs, both small and large, cut out a much higher average of upper grades of lumber than do oak logs. The average value of poplar lumber cut in Tennessee mills in 1911 was $7.54 higher per 1,000 board feet than oak, and from $12 to $18 higher than chestnut, gum, and shortleaf (or yellow) pine. This usually makes it profitable to saw much smaller

Fig. 9.—High grade oak and poplar logs to be shipped to outside markets. Jonesboro.

logs of poplar than of other species. Poplar bolts of a minimum diameter of 12 inches are utilized for fruit package veneers; of six inches, for crating; and of 4 inches, for excelsior and wood pulp. The length of the bolts varies from 4 to 5 feet. Small straight and clear poplar logs 10 feet long and from 6 to 16 inches in diameter at the top end can sometimes be sold profitably for turned porch columns, for which purpose they bring from $10 to $15 per 1,000 board feet.

Value of poplar logs and bolts (based on prices existing in 1914*) delivered f. o. b. cars or on water or at local mills on railroad or water transportation*

Large select saw and veneer logs
28 inches and up in diameter.....$25 to $35 per 1,000 bd. ft.
24 to 28 inches in diameter.....$20 to $25 per 1,000 bd. ft.
20 to 24 inches in diameter.....$15 to $20 per 1,000 bd. ft.
(1-3 off of above prices for common logs.)
(1-2 off of above prices for cull logs.)
Small select and common saw logs.....$10 to $20 per 1,000 bd. ft.
(Poplar yields few, if any, small cull logs.)
Wood pulp, excelsior, and small veneer and crating bolts .....$ 8 to $14 per 1,000 bd. ft.

Hickory.—The chief uses of hickory timber should be for vehicles, handles, sucker rods (for wells), skewers, and parts of agricultural and textile machinery. Large hickory timber can most

Fig. 10.—Hickory bolts for handle stock, worth $7 to $9 per cord, for Nashville market. Williamson County.

profitably be sold as saw logs to be cut into vehicle and wagon dimension stock, for axles, shafts, poles, cross bars, reaches, singletrees, doubletrees, neck yokes, etc. Medium-sized trees can be marketed as saw logs or as spoke or singletree and doubletree bolts and billets.

Small trees, 15 inches or less in diameter, can best be marketed as logs or bolts for ax handles.

Value of hickory logs and bolts (based on prices existing in 1914) delivered at factories and mills in Tennessee

Large clear logs	$20 to $30 per 1,000 bd. ft.
Small clear logs	$15 to $25 per 1,000 bd. ft.
Common logs and bolts	$10 to $15 per 1,000 bd. ft.

Cull logs and bolts have no value.

Hickory logs always cut out a large per cent of unmerchantable cull lumber, frequently 50 per cent from apparently select logs, which keeps down the prices.

Cedar.—The value of cedar for posts and small squares makes possible its utilization down to smaller sizes than any other tree. It is sold chiefly as saw logs, posts, and poles. Most of the cedar left

Fig. 11.—Red cedar from farm woodlots, College Grove, Franklin County.

on farmers' woodlots is comparatively small sap or white cedar, which can often be marketed if cut into from 7 to 10-foot lengths for posts and for squares 2x4 inches and up. These pieces bring from $10 to $20 per 1,000 board feet (mill scale) for logs down to 3 inches in diameter at top end and 7 feet long. The posts and

squares when sawed out sell for from $30 to $60 per 1,000 board feet on cars at local stations, the best being sold for turned porch columns. The next most important use for cedar, and the most profitable where it is large enough, is for poles (peeled), which bring about the following prices delivered at local stations:

$1.60 for 20-foot poles, 6 inch top $2.00 for 25-foot poles, 6 inch top $2.30 for 28-foot poles, 6 inch top	Equivalent to $40 per 1,000 board feet mill cut of squares and posts which could be cut from the same tree.
$ 3.50 for 30-foot poles, 6 inch top $ 8.00 for 40-foot poles, 6 inch top $28.00 for 60-foot poles, 8 inch top	Equivalent to $50, $70, and $90, respectively, per 1,000 board feet of possible squares.

Fig. 12.—Red cedar posts at Telford, in East Tennessee.

The manufacture of red cedar pencil stock is an important industry in the State. This requires practically all red or heartwood, which occurs only in comparatively large and very old trees. Pencil factories will, however, purchase old red cedar rails and stumps of large trees. Material for pencil stock brings from 15 to 20 cents per cubic foot of red wood or from $20 to $30 per 1,000 board feet mill scale. Cedar logs for other purposes, such as lumber for chests, wardrobes, cabinets, coffin boxes, and buckets bring about the same prices.

Chestnut.—Chestnut is sold in Tennessee chiefly as saw logs, shingle bolts, poles, extract wood, and slack cooperage logs and bolts. Large and clear chestnut logs (20 inches and over in diameter) and shingle bolts (in any lengths down to 14″, and 12″ and up in diameter) seldom bring over from $15 to $20 per 1,000 board feet, delivered at local mills, and small logs from $7 to $15. Logs suitable for poles (straight logs 20 feet and up in length and from 6 to 8 inches top end, with bark removed) bring better prices delivered at the railroad, ranging from $20 to $40 per 1,000 board feet.

Fig. 13.—Several thousand cords of chestnut acid wood worth $4.50 per cord at the plant.

In parts of the eastern half of the State extract wood brought, in 1914, from $3 to $4 per long cord (5x4x8 feet) f. o. b. cars, but there is no market for it in the western half. For slack cooperage logs and bolts chestnut is worth, delivered at plants, nearly as much as for small saw logs. Chestnut is lighter and cheaper to handle than oak, although there is often much waste in its manufacture, which is due to unsoundness.

Sweet (or red) gum.—Most of the sweet gum on woodlots in the State is sap gum and only exceptionally is old growth to be found

which will cut out red gum lumber. The chief market is for saw and veneer logs (the latter peeled), bolts for veneer, crating, slack cooperage, and pulpwood, and railroad ties.

Gum logs and bolts are worth about as follows delivered at mills and factories in the State, or in rafts ready for water transportation:

Large select logs (20 inches and up in diameter) from $15 to $20 per 1,000 board feet, f. o. b. cars or at local mills. Common and select logs, 14 to 20 inches and up in diameter, are worth from $8 to $15 in rafts on the Tennessee River, or delivered at local sawmills, or at basket, package, and cooperage plants.

Common logs and bolts from 6 to 14 inches in diameter are worth from $8 to $9 per 1,000 board feet delivered at sawmills and crate and cooperage plants.

Red gum ties delivered on the bank of the Tennessee River are worth from $5 to $7 per 1,000 board feet or from 17 to 25 cents apiece.

Yellow pine.—There is very little yellow pine in woodlots in the State that will make good shipping lumber, and its chief market is a local one. The saw logs may be sold to local mills; and the small stuff, to slack cooperage, box, and crating plants, if there are any in the locality. Common pine dimension lumber and boards for local construction and planing mills bring from $10 to $15 per 1,000 board feet; and select boards, $20, which makes the logs delivered at mills worth $5, $10, and $15 per 1,000 board feet. It is much cheaper to handle pine than oak, and it will usually net a better price than common oak logs when sold to local mills. Large clear pine logs can sometimes be more profitably sold to veneer mills, which pay from $15 to $20 per 1,000 board feet delivered.

Basswood, beech, elm, maple, sycamore, buckeye, and black gum.—Basswood, beech, elm, maple, sycamore, buckeye, and black gum are unimportant in farm woodlots in the State either because of their scarcity or low value. Table 3 (page 140) indicates their relative value for lumber.

Basswood is the most valuable, and beech, which is the most common of these species in woodlots, is the least valuable and can seldom at present be profitably cut into shipping lumber in Tennessee. It is often defective and suitable only for firewood. Good logs from these species can be most profitably marketed as saw logs wherever large enough; small common stuff can be used for slack cooperage. Basswood is as valuable as poplar for pulpwood and excelsior. Bolts of these species for crating and for fruit and vegetable packages of different kinds, and for veneer, are worth from $5 to $10 per 1,000

board feet, log scale, at factories. Black gum is also used for veneer and crating bolts and for wagon hubs.

Ash, walnut, and cherry.—Ash, walnut, and cherry are always most valuable for saw logs in Tennessee (see Tables 3 and 4, pages 140 and 141). Ash is also used locally for pump sucker rods, boat oars, handles, and butter tub staves and heading, chiefly in the western part of the State, for which purposes it is purchased in the form of saw logs and bolts, down to 4 feet in length and 6 inches in diameter.

Fig. 14.—Walnut log, containing 720 board feet, resold on the spot for $72.10 and $97.34. Worth in the tree about $65. The farmer got only $26.

Black locust, dogwood, and persimmon.—As a rule black locust, dogwood, and persimmon are too small for lumber, but they are of considerable value for other purposes. Black locust, when large enough, is chiefly valuable for posts and poles. Black locust posts are worth from 15 to 20 cents apiece delivered, which, figuring 6 board feet per post, is equivalent to from $25 to $35 per 1,000 board feet of lumber. Black locust bolts can sometimes be sold very profitably for insulator pins, for which they bring a little more than for posts. Dogwood and persimmon are valuable chiefly for shuttle stock, for which they bring from $8 to $12 per cord of 160 cubic

Fig. 15.—Twenty-year-old planted black locust, yielding 1,800 posts per acre, worth $300 on the stump.

feet; sticks as small as 4 inches at the top end and 5 feet in length are accepted. This is equivalent to from $16 to $24 per 1,000 board feet of lumber sawed out in the form of small squares.

LUMBER AND LOG VALUES

1. Lumber

Most of the Tennessee lumber shipped out of the State goes to Cincinnati or to the big lumber markets north and east of Cincinnati. At Cincinnati the average prices of one inch lumber of different kinds, grades, and widths during the months of July, August, and September, 1916, were as shown in Table 3, according to a report of the Lumberman's Bureau. These prices usually run from $3 to $6 higher than they do at Tennessee points, since they cover a greater freight charge. The farmer can use current Cincinnati prices, after deducting this freight charge, as a basis for figuring the value of his logs or stumpage in the way described on pages 162 to 172, under "Cost of Production and Net Profits." It would be necessary to estimate the proportion of different grades his timber would cut, as well as cost of producing the lumber from the stump to f. o. b. railroad. Where this can be done it gives the stumpage owner a substantial basis for negotiating with mill men or other purchasers so as to secure the full value of his timber. It should be borne in mind that timber which cuts out an average of No. 1 common in grade is above the average in quality.

2. Logs

Table 4 gives average prices paid for select logs of different kinds and sizes delivered at veneer mills, based on data collected by the Forest Service in 1914; and Table 5 gives the range in price paid by large sawmills f. o. b. local stations for select logs. It should be borne in mind that the prices given in Table 4 are not actual market prices, but are merely a basis for judging the value of select woodlot trees. Ash, which is not included in the table, is usually between white and red oak in price. Common logs are usually worth about two-thirds and cull logs one-half as much as select logs of the same kinds and sizes.

TABLE 3.—*Prices*[1] *of hardwood lumber, one inch and up in thickness, f. o. b. Cincinnati. Variations in price within grades are due to difference in widths and thicknesses*[2].

	1sts and 2nds	No. 1 Common	No. 2 Common	No. 3 Common	Log Run (Mill culls cut)
Ash	$46.00-$72	$31.50-$51.50	$22.00-$28.00	$14.00-$17.00	.....
Basswood	39 50- 44.50	27.50- 34.50	20.50- 26.50	17.50- 19.50	$30.50-$35.50
Beech	24.50- 28.50	18.00- 22.00	14.50- 18.50	.....	19.00- 23.00
Birch (1915 prices)	42.00- 56.00	28.00- 31.00	18.50- 19.50	.....	29.00- 32.00
Buckeye	33.50	21.50	14.00	.....	21.50
Butternut	56.50	26.50	15.00	.....	26.50
Cherry	81.00-123.00	42.00- 73.00	24.00- 26.00	.....	.....
Chestnut	45.00- 48.50	32.00- 35.00	21.00- 24.00	12.00- 13.00	.....
Hickory	52.00- 77.50	31.00- 47.00	19.00- 31.00	.....	.....
Walnut	117.00-151.00	57.00- 80.50	32.00- 42.00	.....	.....
Sycamore—plain	31.50	22.50	16.00	.....	22.50
Sycamore—quartered	46.00	36.00	.....	.....	.....
Plain oak[3]	53.00- 76.50	33.00- 45.00	23.00- 29.00	15.00- 16.00	.....
Quartered white oak[3]	76.50-119.50	46.50- 50.50	27.50- 31.50	.....	.....
Quartered red oak[3]	62.50- 67.00	39.50- 43.50	25.50- 29.50	.....	.....

	1sts and 2nds	Sap and Select	No. 1 Common	No. 2 Common	No. 3 Common
Poplar	$53.00-$65.00	$41.50-$53.50	$31.50-$45.00	$20.50-$27.50	$17.00

	Panel 18-27 inches wide	Wagon box 8-17 inches wide
Poplar	$62.00-$102.00	$39.50-$58.00

	Red 1sts and 2nds	Red No. 1 Common	Sap 1sts and 2nds	Sap No. 1 Common	Sap No. 2 Common
Gum	$34.00-$40.00	$24.00-$30.00	$25.00-$29.00	$19.50-$23.00	$17.50-$18.50

	8-12 inches wide	13-17-inch. wide	18-23-inch. wide	24-27-inch. wide	28 inch. and up
Wide gum (wagon box and panel stock)	$26.50	$31.50	$32.50	$51.50	$61.50

[1]According to market report, Lumbermen's Bureau, September 15, 1916.

[2]The first and lower price given in each case for one inch thick lumber. The higher prices are largely for thicker lumber, for which there is not such a ready market as for inch stock, and on which the carrying charges are usually greater.

[3]Not including oak lumber 2½-5½ inches wide of the 1st and 2nd and No. 1 Common grades, the prices of which is $10 to $20 less.

TABLE 4.—*Average prices for veneer logs of different kinds and sizes delivered at factories in Tennessee, Kentucky, and Indiana per* 1,000 *feet log scale.*

	17 inches and under	18-24 inches	25-28 inches	29-34 inches	35 inches and up
Yellow poplar					
Tennessee	$20.00	$25 50	$28.00	$34.50	$37.50
Kentucky	22.00	32.00	34.65	38.50	15.50
White Oak					
Tennessee	19.00	24.50	28.00	33.00	36.00
Kentucky	20.00	30.00	36.50	41.65	46.00
Indiana	25.50	37.50	49.00	55.50	.....
Red oak					
Tennessee	19.00	21.00	23.50	.....	.....
Indiana	22.60	25.00	37.50	45.00	.....
Walnut					
Kentucky	42.00	60.00	71.00	.....	135.00

Yellow pine and chestnut
Tennessee.....$15 to $20 for select logs of all sizes.

Gum, maple, sycamore, cottonwood, elm
Tennessee.....$10 to $12 for all sizes of log run common and select logs.
Kentucky .....$15 to $20

TABLE 5.—*Range in prices f. o. b. railroads in Tennessee of select saw logs of different sizes per* 1,000 *feet log scale.*

Diameter in inches at top end	White oak[1] poplar and ash	Walnut
12-15	$.....	$30-40
16-17	12-16	40-50
18-19	14-18	50-60
20-21	16-20	60-70
22-23	18-22	70-80
24-25	20-24	80-90
26-27	22-26	90-100
28-29	24-28	100-110
30-31	25-30	110-120
32-33	30-35	
34 and up	35-45	

[1]The range in price for red oak logs $5 to $10 less for those 30 inches and over in diameter and $1 to $5 less for those under 30 inches in diameter.

HOW TO INCREASE PROFITS FROM WOODLOT SALES

Success in woodlot sales, as in marketing agricultural crops, depends upon thorough acquaintance with the various markets, requirements, and prices, and businesslike attention to the details of estimating or measuring, grading, negotiating, and contracting. The farmer who owns timber should not part with it without being satisfied that he is getting the best possible price for every bit of each kind sold. There is usually no need for haste in harvesting and marketing trees. When the market is down, they may be held for more favorable conditions; and in any event there is time for a thorough consideration of the marketing possibilities. The farmer who increases his store of information along any of the following lines will increase his chances of more profitably disposing of his woodlot products: (1) methods of sale, (2) log and lumber scaling and grading, (3) estimating standing timber, (4) knowledge of markets, (5) cost of producing and delivering the different kinds and classes of material, (6) the making of contracts, (7) coöperation with neighbors.

1. Methods of Sale

There are four general ways in which woodlot products may be sold: (1) by the boundary, for a lump sum; (2) by scale measurement of rough products, using the different log, cord, and rick scales; (3) by the piece, for such products as ties and poles; and (4) by lumber scale of sawed products. When conditions are favorable, especially when a portable mill is available and the farmer has some knowledge of lumbering, the last is by far the most profitable method.

To sell advantageously by the boundary for a lump sum requires a careful estimate of the amount and value of the standing timber. Otherwise, sale by scale measurement or by the piece is preferable. Selling by the boundary, however, gives the seller the least trouble, except where restrictions are made in regard to the number, kinds, and size of trees to be cut; these would necessitate supervision to prevent violations.

Profitable selling by scale measurement requires a thorough knowledge of the scale to be used, of the size and grade specifications of the kinds of material which are to be sold, and an agreement in writing in regard to the application of the scale. In small timber, selling by the cord or rick is preferable to selling log scale

because of the unfairness of most log rules in the scaling of small logs. It is a comparatively simple way of marketing. With some classes of material, such as firewood, pulpwood, and excelsior wood, it is used exclusively.

Selling by the piece is also comparatively simple and it is the only method under which some classes of material such as ties, poles, piles, etc., are sold. The important thing is to know the specifications and relative values of the different grades of each class of products so as to utilize the timber cut to the best advantage.

Fig. 16.—Sawmill cutting 8 to 12 thousand board feet daily of logs from farm woodlots.

Selling by lumber scale includes both selling logs at local mills on the basis of the actual amount of lumber they cut out and the selling of lumber itself which the farmer has himself sawed out or had sawed by a portable-mill operator. It is especially advantageous to sell small logs in this way. Selling lumber sawed out by a portable mill set up in the woodlot should be much more used by farmers than it now is, especially where they have disposed of all their high grade saw logs. It is, probably, the surest way of getting the most out of the timber, provided they have the necessary knowledge of the subject. It dispenses with the necessity of grading logs or

making an accurate estimate of the standing timber, and may result in a considerable saving, especially on common and cull logs which can not be hauled out of the woodlot at a profit. The low grades of lumber, of little or no market value, can be kept for use on the farm or for local disposal, and the better grades can often be sold for shipping lumber at prices which will often net as much as if all the timber were sold standing or in the log. Or special orders may be filled for local house construction, or for special stock for shipment to wood-using factories and dealers in hickory whiffletree squares, spoke squares, or handle stock, oak felloe stock, tight cooperage stock, or car and bridge timbers, ash baseball bat or long handle stock, dogwood and persimmon shuttle blocks, cedar squares and posts, and locust insulator pins. It will usually be possible to have the milling done by contract, but the owner should attend to the logging himself and keep an eye on the milling.

When selling by lumber scale, it is decidedly advantageous to have as complete a knowledge as possible of sawing, scaling, and grading lumber. Scaling is relatively simple, but grading is a complicated subject, requiring considerable experience. If the lumber is sold at the tail of the mill, it is best to employ an experienced grader or to study the grading rules to an extent sufficient to detect gross errors. The standard grading rules in Tennessee are those of the Hardwood Manufacturers' Association, a copy of which can be secured on application to the Secretary of the Association, Cincinnati, Ohio; and the National Hardwood Lumber Association, of Chicago, Ill.

2. Scaling and Grading Logs and Bolts

Scaling logs.—For obtaining the lumber contents of logs of different sizes there are a number of log rules, of which the Doyle-Scribner* is the one most generally used in Kentucky. It is a combination of the Doyle rule, for logs 28 inches and under, and the Scribner rule, for logs over 28 inches. The volumes which it gives are those indicated by heavy faced type in Table 6. It will be seen that this combination of the two is in the interest of the buyer of logs, as it gives a lower scale than either rule does taken separately. It would be fairer to combine these rules the other way around,

*This Doyle-Scribner rule is often erroneously called the Doyle rule, and sometimes the Scribner rule.

making a Scribner-Doyle rather than a Doyle-Scribner combination, in which case the seller of logs would get from 25 to 100 per cent more scale for logs 12 inches and under in diameter than he does by the Doyle-Scribner rule.

For scaling logs rafted by river the Cumberland River rule* is commonly used in the State. This rule is even more unfair to the seller than the Doyle-Scribner, except on logs less than 12 inches in diameter.

For comparison with the Doyle-Scribner and Cumberland River rules the Champlain rule, which is not in use in the State, is also given in Table 6. This rule is made for sound and straight logs and shows what it is possible for the mill man to saw out of such logs with careful manufacture. It is especially important to note in this table that the scale for small logs from 6 to 10 inches in diameter by the commonly used Doyle rule is from one-half to one-fifth as much as by the Champlain rule. In using the Doyle rule for small logs the mill man, or purchaser of logs, may argue that the great overrun in mill scale which he gets from them, no more than counterbalances the greater cost of manufacture and the lesser value of the lumber produced from small than from large logs, in which statement there is a certain amount of truth. But the difference in value of large and small logs is often fully provided for by difference in price, in which case there is no reason for the very much too small scale allowed for them by the Doyle rule.

The scaling is done by measuring the length of the log and its average diameter inside bark at the top end, and then recording from the log rule the lumber contents given for the dimensions of the log. Buyers often scale logs on the basis of the smallest diameter, instead of the average, which is obviously to their advantage. Logs are scaled to full inches in diameter inside bark; a fraction of one-half inch and less is thrown out, a greater fraction is read as a full inch. The contract of sale (pp. 172 to 176) should be definite in

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*This rule was constructed for measurement of hardwood logs in the water in the Mississippi River and its tributaries. These logs are often defective and in the water it is impossible to distinguish the defects hidden by the water itself, and by mud, sand, plugs, etc. This log rule is supposed to allow for all such hidden defects, and it would be manifestly unfair when applied to fairly sound and good logs.

TABLE 6.—*Log rules for board feet measure of logs of different lengths and diameters.*

Length of log and name of rule	DIAMETER BETWEEN BARK AT SMALL END OF LOG IN INCHES																									
	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	22	24	26	28	30	32	34	36	38	40
Eight-foot logs	CONTENTS OF LOG IN BOARD FEET																										
Doyle	0	0.5	2	4.5	8	12	18	24	32	40	50	60	72	84	98	112	128	162	200	242	288	338	392	450	512	578	648
Scribner	4	6	9	12	16	21	27	32	39	49	58	71	79	93	106	120	140	167	202	250	290	329	368	400	462	535	602
Cumberland ..	4	6	9	11	15	19	24	29	34	40	47	53	61	69	77	85	95	115	137	160	186	213	243	274	314	343	379
Champlain ...	4	7	11	16	21	28	35	43	52	62	73	84	97	110	124	139	154	188	225	266	310	357	407	462	519	580	643
Ten-foot logs																											
Doyle	0	0.6	2.5	5.6	10	16	23	31	40	50	62	75	90	106	122	141	160	202	250	302	360	422	490	562	640	723	810
Scribner	6	8	11	15	20	26	34	40	49	61	72	89	99	116	133	150	175	209	252	313	363	411	460	500	577	669	752
Cumberland ..	5	7.5	11	14	19	24	30	36	43	50	58	67	76	86	96	107	118	148	171	200	232	267	303	348	384	428	474
Champlain ...	5	9	14	20	27	35	44	54	65	78	91	105	121	137	155	173	193	235	282	332	387	446	509	577	649	724	804
Twelve-foot logs																											
Doyle	0	0.8	3	6.8	12	19	27	37	48	61	75	91	108	127	147	169	192	243	300	363	432	507	588	675	768	867	972
Scribner	7	10	14	18	24	32	40	48	59	73	86	107	119	139	160	180	210	251	303	375	436	493	552	600	692	801	903
Cumberland ..	6	9	13	17	23	29	36	43	51	60	70	80	91	103	115	128	142	172	205	240	279	320	364	411	461	514	569
Champlain ...	6	10	17	24	32	42	53	65	78	93	109	126	145	165	186	208	231	282	338	399	465	535	611	692	778	869	965
Fourteen-foot logs																											
Doyle	0	0.9	3.5	7.9	14	22	32	43	56	71	88	106	126	148	171	197	224	283	350	423	504	591	686	787	896	1,011	1,134
Scribner	8	11	16	21	28	37	47	56	69	85	100	125	139	162	187	210	245	292	353	439	509	575	644	700	807	934	1,053
Cumberland ..	7	10.5	15	20	27	34	41	50	60	70	81	93	106	120	134	149	166	201	239	280	325	373	425	479	538	599	664
Champlain ...	7	12	19	28	38	49	62	76	92	109	127	147	169	192	217	243	270	329	394	465	542	625	712	808	908	1,014	1,126
Sixteen-foot logs																											
Doyle	0	1	4	9	16	25	36	49	64	81	100	121	144	169	196	225	256	324	400	484	576	676	784	900	1,024	1,156	1,296
Scribner	9	13	18	24	32	42	54	64	79	97	114	142	159	185	213	240	280	334	404	500	582	657	736	800	923	1,068	1,204
Cumberland ..	8	12	17	23	31	39	47	57	68	80	93	107	121	137	153	171	190	229	273	320	372	427	485	548	614	685	759
Champlain ...	8	14	22	32	43	56	70	87	105	124	146	168	193	219	247	277	308	376	450	532	620	714	814	923	1,038	1,159	1,287

these particulars, as well as in those relating to grading the logs, deducting for defect, etc., which follow.

TABLE 7.—*Number of cords of round wood bolts (4 feet long) contained in 1,000 board feet of 16-foot logs of different top diameters when scaled by Doyle, Scribner, and Champlain log rules.*

Top diameter of logs, inside bark, in inches	Number of cords in 1,000 board feet of logs		
	Logs scaled by Doyle rule	Logs scaled by Scribner rule	Logs scaled by Champlain rule
	A. Cords of unpeeled wood		
4	....	5.0	5.6
5	59.2	4.6	4.2
6	18.4	4.1	3.3
7	9.8	3.7	2.8
8	6.6	3.3	2.5
9	4.9	2.9	2.2
10	3.9	2.6	2.0
11	3.3	2.5	1.8
12	2.8	2.3	1.7
	B. Cords of peeled wood		
4	....	3.8	4.3
5	46.0	3.5	3.3
6	14.7	3.3	2.7
7	8.1	3.0	2.3
8	5.6	2.8	2.1
9	4.2	2.5	1.9
10	3.4	2.3	1.8
11	2.9	2.2	1.7
12	2.5	2.1	1.6

Scaling bolts in log measure.—When the wood is to be sold as stock for cooperage, veneer, handles, pulp, or excelsior, the farmer will often have the choice of selling it as small logs by log scale, or by the cord of short bolts. In order to determine the comparative advantage of selling small logs, 12 inches and less in diameter at the top end, by the standard cord (4x4x8 feet in size, containing 128 cubic feet), the figures in Table 7 may be used. These will apply only when the length of the bolt which would be required if the wood were cut into bolts is 4 feet. If greater or less than 4 feet, so that a stack 4 feet high and 8 feet long would contain more or less than 128 cubic feet, the figures should be proportionately increased or reduced. The decision whether to sell in logs or bolts must, of course, take into account the greater cost of cutting into bolts than into logs.

Grading logs.—There is considerable variation in the practice of grading logs. They are commonly graded as select, common, and cull, depending on their relative clearness and the proportion of different grades of lumber which they will produce. A common log brings at the mill about two-thirds as much as a good log, and a cull log half or even less. Sometimes the cull logs are rejected entirely. In general, the three classes may be defined as follows:

1. *Select logs.* Logs which will saw out 75 per cent of No. 1 Common or better, or 50 per cent 1 and 2 Select lumber. Small logs must be practically clear and free from defects; from one to three small or medium sized knots are admitted on medium sized or large logs, or one large knot if near the end of the log.

2. *Common logs.* Logs which will cut 75 per cent No. 2 Common and better, or 50 per cent No. 1 Common and better. This includes logs with from one to three large knots, depending upon the size of the log, or with a number of small tight knots whose total area will not exceed that of from 1 to 3 large knots.

3. *Cull logs.* Logs which will not cut 75 per cent No. 2 Common and better. This includes all large knotted logs which will cut out only No. 2 Common and cull lumber.

At large mills located in large towns and cities more grades are often recognized; and the prices paid for logs of the good or select grade of valuable species vary greatly according to the size of the logs. (See Table 5.)

The following grades and prices, in use at one of the large mills in Nashville in 1914, may be taken as representative of log grading by large mills in the State:

Poplar, clear or nearly so

	Price paid per 1,000 bd. ft. log scale
(One-third off for common and one-half off for culled logs)	
No. 1 log, 28 inches and up in diameter	$30 to $35
No. 2 log, 24 to 28 inches	$25
No. 3 log, 20 to 24 inches	$20

Poplar, common logs

No. 4 log, 15 to 20 inches	$12.50

White oak and ash, clear or nearly so

(One-third off for common and one-half off for culled logs)

No. 1 log, 28 inches and up in diameter	$35 to $45
No. 2 log, 24 to 28 inches	$27.50
No. 3 log, 18 to 24 inches	$22.50

White and red oak, common logs

No. 4 log, 13 to 18 inches	$12.50
No. 5 log, 12 inches and under	$5 to $10

Red oak $3 to $5 less per 1,000 than white oak No. 1, No. 2 and No. 3 logs and about the same on lower grades.

Inferior species, such as beech, maple, and sycamore were classified by this mill as No. 5 logs at from $5 to $10 per 1,000 board feet, log scale, regardless of size.

Deduction for defect.—In the contract of sale, stipulations should be made as to the amount to be deducted from the log scale in allowing for visible defects, such as crookedness and unsoundness. The U. S. Department of Agriculture Forest Service Manual for Scaling Timber (1915) contains the following instructions for deducting for defect:

Deductions should not be made for defects outside of the cylinder represented by the top end and total length of the log or for defects in the portion of the log which will be slabbed off. Otherwise deductions should be made in scaling for all visible defects which will actually reduce the yield of lumber from the log. This includes crooks and any defective or waste material whose presence is plainly indicated on the surface of the log by conks, rotten knots, pitch seams, etc. There must, however, be an unmistakable surface indication of the defect. The scale should never be reduced simply because hidden defect frequently appears in sawing.

The total scale of the log will be reduced in each instance by the estimated loss in lumber from the defects present in the cylinder as compared with a sound cylinder of the same dimensions. Reductions will not be made for defects in the swell of the log outside of the cylinder. Scalers should reduce the scale for all other defects regardless of overrun.

Deductions will not be made for "sound" defects, such as sound knots, however large, and firm rot, which affect the grades of lumber but do not reduce the total cut from the log. Deductions will be made only for crooks, curve or sweep, and checks, worm holes, and pitch rings.

The percentage of waste from sweep or curve varies with the diameter of the log. A curve of 3 inches in a 10-inch log will cause approximately twice the proportionate waste as the same curve in a 20-inch log. Sweep which would cull a very small log would not necessarily cause the rejection of a large log.

The scaler should sight along a curved log, noting where the saw will square it sufficiently to cut boards on both sides affected by the curve. In

determining the amount of loss it should be remembered that material near the slab saws out narrow boards containing fewer feet than those cut from any other part of the log..

No deduction should be made for curve or sweep in logs over 16 feet long.

3. Estimating the Standing Timber

A proper estimate of the woodlot involves the determination of the contents of all the trees in it in terms of the most common forms in which timber is marketed, such as logs, bolts, poles, ties, etc. The determination of the units in which to estimate the timber requires some general knowledge of the market requirements as to form, size, etc., for the different kinds of trees. Often two or more units should be used for a single tree. Thus a large white oak might yield a fine, clear veneer log, valuable enough to be shipped a long distance, and in addition, one or two common logs suitable for local manufacture, some railroad ties, and some posts and cordwood. Again, the same part of the tree might appear to be about equally valuable for several purposes, in which case a separate estimate should be given it for each purpose. Hickory, for example, can advantageously be estimated in terms both of cords of handle material and of board feet of vehicle stock, provided it is marketable for both of these uses. Usually, however, the purpose for which the tree is most valuable can be determined in advance and the estimate made with reference to this one use.

A simple method of estimating is to record the diameter and length of each piece or tree and from these two figures determine the volume of the piece in the desired form by the use of the log rule and volume tables. The work is not difficult, but it is impossible to put too much care into it; a careless estimate will mislead and is likely to be worse than none. For recording the estimated diameters and lengths, a form similar to that shown in Table 12 is convenient. It provides spaces for recording dimensions by both the log rule and the volume table method. The log rule method is the more accurate and it should be used for valuable timber. The diameter and lengths of the logs of different grades and sizes are recorded separately for each tree. When, as is sometimes the case, only one grade or one class of material is contained in the woodlot, the recording is simplified; as, for example, when the logs are fit only for common or small lumber, or when the material is suitable or is to be used entirely for ties, poles, piles, etc.

The diameter breasthigh (outside bark at 4½ feet from the ground) is important, since it affords a good basis for judging the diameters at the log ends. On valuable timber at least, it should be actually measured rather than estimated.* Top diameters of logs, bolts, etc., must, of course, be estimated. The double bark thickness should be deducted and the estimate recorded as inside bark. In estimating top diameters it is useful to have in mind an idea of the approximate rate at which the tree tapers. A good general rule for ordinary trees over 12 inches breasthigh is to assume that the diameter inside bark at stump height is the same as that outside bark at breasthigh, and then allow about 3 inches taper for the first 8 feet of log length above the stump and 1 inch taper for each succeeding 8 feet. For trees under 12 inches breasthigh, one-half this amount should be allowed. Often, of course, there will be trees which obviously have greater or less taper than these average figures allow for, and the observer's judgment must guide him in deducting for the taper.

The merchantable lengths of especially valuable timber should be measured, if possible, with some instrument designed for this purpose, or at least by holding a 12 or 16 foot pole against the tree. The lengths of select logs are most important to determine accurately, and these are usually limited to the lower part of the tree, which can be measured with a pole.

Since defects of different kinds often cut down the scale a good deal, the observer should keep special notes of all observable injuries, malformations, or signs of rot likely to influence the amount and quality of the product.

The volume table method of estimating requires only a record of the diameter breasthigh of each tree, and either the number of 16-foot logs it contains or its total height. With these data the volumes can be obtained from the appropriate volume table (Tables 8-11). When it is desired to estimate the more valuable trees in log lengths and the less valuable as entire trees, the record for both can be made on the same sheet, as illustrated in Table 12. To assist the eye in estimating total heights and log lengths, the measurement of a few felled trees will be helpful.

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*The measuring can be done by means of tape, caliper, or measuring stick. For a description of the use of these implements, see U. S. Dept. of Agriculture, Farm. Bul. 715, "Measuring and Marketing Woodlot Products."

TABLE 8.—*Contents in board feet of hardwood trees of different diameters and merchantable heights.*

(Stump height, 2 feet. Trees over 75 years old. Scribner Decimal C rule.)

Diameter breasthigh Inches	NUMBER OF 16-FOOT LOGS.								Diameter inside bark at top. Inches	Number of trees measured as a basis for this table
	1	1½	2	2½	3	3½	4	4½	5	
	VOLUME—BOARD FEET.									
8	20	27	35	43	....	....	....	....	....	6	..
9	20	32	42	53	....	....	....	....	....	6	1
10	20	36	52	64	81	....	....	....	....	6	2
11	21	43	62	78	98	120	....	....	....	6	4
12	23	50	73	93	120	140	180	....	....	6	3
13	25	58	86	110	140	170	200	....	....	7	4
14	27	67	100	130	160	190	230	260	....	7	9
15	30	77	120	150	180	220	260	300	....	8	15
16	34	89	130	170	200	250	290	340	390	8	18
17	38	100	150	190	230	280	320	380	440	9	40
18	43	120	170	210	260	310	360	420	490	9	56
19	48	130	200	240	290	350	400	470	540	10	65
20	54	150	220	270	330	390	450	520	590	10	75
21	62	170	250	300	370	440	500	580	650	11	86
22	69	190	270	340	410	480	550	640	720	11	90
23	77	210	300	380	450	530	610	700	790	12	67
24	85	230	340	420	500	580	670	770	860	12	80
25	93	250	370	460	550	640	740	840	940	13	56
26	100	280	410	510	600	700	810	910	1,020	13	89
27	110	300	450	560	660	770	880	990	1,110	14	68
28	120	330	490	610	720	830	960	1,080	1,200	14	81
29	130	360	530	660	780	900	1,030	1,160	1,300	15	61
30	140	390	580	720	850	980	1,120	1,250	1,400	15	47

31	420	630	770	910	1,050	1,200	1,350	1,510	16	45
32	450	690	830	980	1,130	1,290	1,450	1,620	16	40
33	480	740	890	1,050	1,211	1,380	1,560	1,730	17	49
34	..	800	950	1,120	1,290	1,480	1,670	1,860	17	30
35	..	860	1,010	1,180	1,380	1,570	1,790	1,990	18	22
36	..	920	1,070	1,250	1,460	1,680	1,910	2,140	18	17
37	..	..	1,130	1,320	1,550	1,780	2,040	2,290	19	24
38	..	..	1,190	1,390	1,640	1,890	2,170	2,450	19	11
39	..	..	1,250	1,460	1,730	2,000	2,300	2,600	20	16
40	..	..	1,311	1,540	1,820	2,120	2,430	2,760	20	15
41	..	..	....	1,610	1,910	2,240	2,570	2,930	21	6
42	..	..	....	1,680	2,000	2,360	2,720	3,100	21	3
43	..	..	. ..	1,750	2,090	2,470	2,860	3,270	22	3
44	..	..	....	1,830	2,180	2,590	3,010	3,450	22	2
										1,300

Correction factors for different species:

Chestnut—For diameters up to 40 inches, subtract 10 per cent.
Chestnut oak—For diameters of 32 to 40 inches, add 10 per cent.
Red oak—For all diameters use the table without change.
White oak—For diameters of 18 to 40 inches, add 10 per cent.
Yellow poplar—For diameters of 8 to 40 inches, use table without change.

TABLE 9.—*Contents in board feet of coniferous trees of different diameters and merchantable heights.*

(Stump height, 2 feet. Diameter (inside bark) of top, 6 inches. Trees over 75 years old Scribner Decimal C rule.)

Diameter breasthigh Inches	TOTAL HEIGHT OF TREE—FEET.										Number of trees measured as a basis for this table
	60	70	80	90	100	110	120	130	140	150	
	VOLUME—BOARD FEET										
8	27	31	38	46	63	....	....	....	....	....	12
9	38	47	54	64	80	....	....	....	....	....	9
10	51	63	71	84	100	110	....	....	....	....	12
11	65	80	91	110	120	140	....	....	....	....	13
12	80	98	110	130	150	170	....	....	....	....	8
13	96	120	140	160	180	200	....	....	....	....	4
14	110	140	160	180	210	240	270	....	....	....	7
15	130	160	190	220	250	280	310	....	....	....	11
16	160	190	220	250	280	320	350	380	....	....	20
17	180	210	250	290	320	360	400	440	....	....	21
18	210	240	290	330	370	410	450	490	....	....	20
19	240	280	320	370	410	460	500	550	....	....	34
20	270	320	360	420	470	520	560	620	680	....	27
21	310	360	410	470	520	580	630	690	750	....	33
22	350	410	460	520	580	640	700	760	830	....	40
23	390	460	520	580	640	710	770	840	910	....	37
24	440	510	570	640	710	780	850	920	1,000	1,090	37
25	..	570	640	700	780	850	930	1,000	1,090	1,190	47
26	..	630	700	770	840	920	1,010	1,090	1,190	1,290	52
27	..	690	770	840	920	1,000	1,090	1,180	1,290	1,400	43
28	..	760	840	910	990	1,080	1,180	1,280	1,390	1,510	45
29	..	830	910	990	1,070	1,160	1,260	1,370	1,500	1,630	39
30	..	900	990	1,070	1,150	1,240	1,350	1,470	1,610	1,760	47

31	...	1,070	1,150	1,230	1,330	1,450	1,580	1,730	1,900	40
32	...	1,160	1,230	1,320	1,410	1,540	1,690	1,860	2,050	44
33	...	1,240	1,320	1,400	1,500	1,640	1,800	1,990	2,180	39
34	...	1,320	1,400	1,490	1,600	1,740	1,920	2,120	2,330	36
35	...	1,410	1,490	1,570	1,690	1,850	2,040	2,250	2,470	34
36	...	1,490	1,570	1,660	1,790	1,950	2,160	2,380	2,610	29
37	...	....	1,650	1,740	1,880	2,060	2,270	2,510	2,760	25
38	...	....	1,740	1,830	1,980	2,170	2,390	2,640	2,900	18
39	...	....	1,820	1,910	2,070	2,270	2,500	2,770	3,050	18
40	...	....	1,900	1,990	2,170	2,380	2,630	2,910	3,210	24
41	...	....	1,990	2,080	2,270	2,490	2,750	3,050	3,360	11
42	...	....	2,070	2,170	2,360	2,600	2,880	3,200	3,530	11
43	...	....	....	2,260	2,460	2,710	3,010	3,350	3,700	11
44	...	....	....	2,350	2,560	2,830	3,150	3,510	3,880	3
45	...	....	....	2,430	2,660	2,960	3,300	3,670	4,060	7
46	...	....	....	2,520	2,760	3,090	3,450	3,850	4,250	5
										973

Correction factors for different species:

Hemlock—For diameters of 8 to 10 inches.....add 10 per cent.
Hemlock—For diameters of 11 to 20 inches.....add 22 per cent.
Hemlock—For diameters of 21 inches and up.....add 20 per cent.
Red spruce—For diameters of 8 to 10 inches.....add 5 per cent.
Red Spruce—For diameters of 11 inches and up.....add 25 per cent.
Shortleaf pine—For diameters of 10 inches and under.....add 15 per cent.
Shortleaf pine—For diameters of 11 to 19 inches.....add 25 per cent.
Shortleaf pine—For diameters of 20 to 23 inches.....add 35 per cent.
Shortleaf pine—For diameters of 24 inches and over.....add 40 per cent.
White pine—For all diameters, use the table without change.

TABLE 10.—*Contents in cubic feet, and number of cubic feet per cord in hardwood trees of different diameters and total heights.*

Diameter breasthigh Inches	Total height of tree—Feet									*No. cu. ft. per cord
	20	30	40	50	60	70	80	90	100	
	Peeled volume—cubic feet									
2	.2	.3	....	....	....	....	....	....	....	63
3	.4	.6	.8	....	....	....	....	....	....	70
4	.7	1.1	1.5	1.8	....	....	....	....	....	75
5	1.1	1.7	2.3	2.9	3.4	....	....	....	....	79
6	1.6	2.5	3.3	4.1	4.9	5.8	....	....	....	83
7	2.2	3.4	4.5	5.6	6.7	7.9	9.0	....	....	85
8	2.9	4.4	5.9	7.3	8.8	10.3	11.7	13.2	....	88
9	3.7	5.6	7.4	9.3	11.1	13.0	14.8	16.7	18.6	89
10	4.6	6.9	9.2	11.5	13.7	16.0	18.3	21	23	91
11	...	8.3	11.1	13.9	16.6	19.4	22	25	28	92
12	...	9.9	13.2	16.5	19.8	23	26	30	33	93
13	...	11.6	15.5	19.4	23	27	31	35	39	94
14	...	13.5	18	22	27	31	36	40.	45	94
15	...	15.5	21	26	31	36	41	46	52	95
16	...	....	23	29	35	41	47	53	59	95
17	...	....	26	33	40	46	53	60	66	95
18	...	....	30	37	45	52	59	67	74	95
19	...	....	33	41	50	58	66	74	83	96
20	...	....	37	46	55	64	73	82	92	96

Per cent of bark to total volume for trees of different species and diameters

Species	Diameter breasthigh—Inches				
	6	12	20	30	40
	Per cent of bark				
Ash, black	18	16	13	10	..
Ash, green	22	17	13	10	9
Ash, white	22	19	15	11	..
Basswood	..	20	18	16	14
Beech	8	7	7	..	..
Birch, yellow	..	13	13	13	..
Maple, sugar	..	17	17	17	..
Hemlock	15	17	18	19	..
Hickories	21	17	15	13	..
Poplar, yellow	21	17	..	..	..

*From Forest Service Bulletin 96, p. 64.

TABLE 11.—*Contents in cubic feet, and number of cubic feet per cord in the tops (exclusive of branches), of hardwood trees of different diameters and total heights. By top is meant the portion of the stem above the merchantable length.*

Diameter breasthigh	Diameter at top of merchantable length	Total height of tree—Feet								Number cu. ft. per cord of topwood
		50	60	70	80	90	100	110	120	
		Peeled volume of top—Cubic feet								
Inch.	Inch.									
8	6	1.2	1.5	1.8	....	....	....	....	....	66
9	6	1.3	1.6	1.9	....	....	....	....	....	66
10	6	1.4	1.7	2.0	2.1	....	....	....	....	66
11	6	1.5	1.9	2.2	2.3	....	....	....	....	66
12	6	1.7	2.1	2.4	2.5	3.1	....	....	....	66
13	7	1.9	2.4	2.7	3.0	3.6	....	....	....	69
14	7	2.1	2.7	3.1	3.5	4.2	4.7	....	....	69
15	8	2.3	3.1	3.5	4.0	4.8	5.4	....	....	71
16	8	2.6	3.5	4.0	4.7	5.5	6.2	6.7	....	71
17	9	2.9	3.9	4.6	5.4	6.3	7.0	7.6	....	74
18	9	3.2	4.4	5.2	6.1	7.2	8.0	8.6	9.2	74
19	10	3.6	4.9	5.9	6.9	8.1	9.0	9.8	10.4	77
20	10	4.0	5.4	6.6	7.8	9.0	10.0	11.0	11.7	77
21	11	4.4	5.9	7.3	8.7	10.0	11.1	12.3	13.1	79
22	11	4.8	6.5	8.0	9.6	11.0	12.2	13.6	14.5	79
23	12	5.3	7.1	8.8	10.6	12.2	13.4	15.0	16.0	81
24	12	5.8	7.7	9.6	11.6	13.4	14.7	16.5	17.6	81
25	13	6.3	8.3	10.4	12.6	14.6	16.0	18.0	19.2	83
26	13	6.8	9.0	11.3	13.7	15.8	17.3	19.5	21	83
27	14	....	9.7	12.2	14.8	17.1	18.8	21	23	85
28	14	....	10.4	13.2	16.0	18.5	20	23	24	85
29	15	....	11.1	14.2	17.2	20	22	24	26	87
30	15	....	11.9	15.2	18.5	21	24	26	28	87
31	16	....	12.7	16.2	19.8	23	25	28	30	88
32	16	....	13.5	17.3	21	25	27	30	32	88
33	17	....	....	18.4	23	26	29	32	35	90
34	17	....	....	19.5	24	28	31	34	37	90
35	18	....	....	21	26	30	33	36	39	91
36	18	....	....	22	27	31	35	38	41	91
37	19	....	....	....	29	33	37	40	44	93
38	19	....	....	....	30	35	39	42	46	93
39	20	....	....	....	....	37	41	45	49	94
40	20	....	....	....	....	39	43	47	51	94

TABLE 12.—*Form for recording measurements of standing timber. Location and area: One-quarter acre at east end of woodlot, and representative of ten acres.*

Best Timber Trees	Diameter Breast-high Inches	MERCHANTABLE LOGS						REMARKS
		Select		Common		Cull		
		Length Feet	D.I.B.* Inches	Length Feet	D.I.B.* Inches	Length Feet	D.I.B.* Inches	
White Oak	24	16	20	32	16	12	14	Plus 3 ties; 6 posts.
Red Oak	30			50	20			
Hickory	20	32	14					Whiffle tree stock
Walnut	25	16	20	16	18			Plus 20 posts
White Oak	30	24	24	30	18			Plus 10 ties
White Oak	16			50	6			Piling only
Red Oak	20			32	14			
Hickory	25	16	20					Remainder Firewood
Chestnut	20			60	6			Pole only
Cedar	15			40	6			Pole only.
Etc.								

* D.I.B. diameter inside bark at top end of log.

Less Valuable Trees.

Diameter Inches	White Oak	Red Oak	Hickory	Walnut	MISCELLANEOUS
4	III (50)†	II	III		III (25)
6	II	I	II		IIII (30)
8	I (60)	I	I		III (35)
10	IIII			IIII (80)	II (40)
12		I	III (52)		II (45)
14	II (64)	II			II (50)
16		I	I		I (55)
18	I	I			I (62)
20					I (70)

†Circled Figures indicate average heights.

Fig. 17.—Large size hickory oak and red gum on second bottoms Carroll County.

Sizing up every tree in the woodlot or at least each of the more valuable ones will as a rule give closer results than basing the estimate of the whole tract on one or more carefully estimated sample areas. The work does not have to be done all at once; and by marking the point where he is compelled to stop, the farmer may do only part of the estimating at a time and thus cover his entire woodlot without neglecting other duties. Where it is necessary to employ the sample plot method, the area of all the plots together should be as large as possible, though the plots themselves may be small. They should be scattered through the woodlot so as to represent as closely as possible average conditions. A convenient size for a single plot is one-quarter acre (roughly a square measuring 104x104 feet, a strip 52x209 feet, or a circle 20 paces—59 feet—in radius). The yield on the sample plots should be totalled for each of the kinds and classes of material, the average amount per acre of each kind determined, and this amount multiplied by the total number of acres in the woodlot.

4. KNOWLEDGE OF MARKETS.

The woodlot owner must secure detailed information on markets in order to sell most profitably. Examination of local markets should come first, and should be the most detailed, as a large proportion of woodlot products can only be shipped outside the local market in manufactured or partially manufactured form. Investigation should then be extended in increasing circles to outside markets for more valuable products, such as high grade logs or specially sawed or rived stock, which can often be shipped long distances and sold at a greater profit than if disposed of near by. Local markets, where the net profits may be the same, are preferable to outside markets because of the closer relationship possible between buyer and seller. They also offer, as a rule, a much wider range of utilization and require a less degree of manufacture.

The following kinds of markets should be investigated:

1. High grade logs,—large saw and veneer mills, local or at a distance.

2. Common and cull logs,—chiefly local sawmills and slack cooperage plants.

3. Ties.—near-by railroad and local and outside dealers.

4. Poles,—local and outside dealers and telephone and telegraph companies.

5. Piling,—railroads, dock companies, and dealers in large cities.

6. Posts,—the local market, and dealers in large cities.

7. Bolts (for vehicle stock, handles, cooperage, shuttles), near-by factories, or points within a very cheap railroad haul.

8. Sawed or rived stock (for vehicles, handles, cooperage and shuttles),—wide range of factories, local or distant.

9. Lumber,—local market, and dealers and wood-using plants, especially planing mills, in large towns and cities. Much the larger part of the lumber cut from woodlots will be of low grade, which

Fig. 18.—White oak logs for the Memphis market. Fayette County.

it will not pay to try to sell at any great distance on account of freight charges.

10. Cordwood,—consumers, local dealers, or dealers within a very cheap railroad haul.

11. Tanbark,—local dealers, local or distant tanneries.

12. Mining timbers,—local mines only, as the mines are located in regions of abundant local supply of forest products.

The chief market possibilities of the different species of trees are indicated on pp. 120 to 125, under "The Uses of Native Woodlot Trees." Reference to these topics will assist the prospective seller in narrowing down the field of his investigations, and in avoiding

useless correspondence. On pages 178 to 195 of this bulletin are given the names of a large number of wood-using plants and dealers in forest products. From this list the woodlot owner can select those which appear likely to be in the market for the particular classes of products he has for sale, and which do not appear to be at a prohibitive distance. In writing to these, state as clearly and briefly as possible the kind and amount of products for sale, and ask that prices and specifications be sent in case the firm is in the market for the products mentioned. It is well to ask also for the favor of any information regarding other possible markets in case the addressee can not purchase.

5. Costs and Profits

There is often a variety of ways of marketing each kind and size of tree in the woodlot. The choice depends not only upon the prices offered, but also upon the cost of getting the material out in the required form. The real basis on which decisions should be made is the net or stumpage value of the product. This is obtained by subtracting the total (estimated) cost of production, including haul to the point of delivery, from the price anticipated. When the timber is sold on the stump, this computation is of course unnecessary. Otherwise it may include the costs of felling, cutting up, peeling, splitting or riving, stacking, swamping and skidding, hauling, loading, sawing and handling lumber, and freight. On pages 163 to 166 are listed the approximate costs of these operations for different kinds of products.

The following example illustrates the use of these figures in computing the possible net profits (or stumpage values) which could be obtained from the same material if sold for different uses. A farmer living eight miles from a railroad wishes to sell some "common" oak timber. The distance and roads are such as to permit of but one round trip haul per day for one team. He finds two possible purchasers; one, a dealer in a near-by town who offers $20 per 1,000 board feet, delivered, of oak dimension lumber; the other, a local mill at a distance permitting one haul per day, which offers $10 per 1,000 board feet, log scale, delivered, for the common run of oak saw logs. To produce the dimension lumber he could have a portable mill set up in his timber, so that the cost of hauling the logs to the mill would be avoided; and he would estimate his costs

of cutting and skidding the logs and manufacturing, handling, hauling, and loading the lumber as being equal to those given as average on page 164. In addition, there would be the item of railroad shipment at, say, 10 cents per 100 pounds, or $4 per 1,000 board feet. If he sold to the sawmill, his costs would include cutting and hauling (say 600 board feet of logs per load), but no skidding. In addition, there would be a mill overrun* amounting to 33 per cent, which would make the price offered for the logs by lumber scale $7.50 per 1,000 board feet, as the mill operator would get 1,333 board feet of lumber for his $10.

The net or stumpage value for the timber in the two cases would be figured as follows:

1. *Timber sold as lumber at* $20 *per* 1,000 *board feet, lumber scale.*

Cutting and skidding to sawmill	$ 4.25
Manufacture, handling, hauling, loading	8.50
Freight	4.00
Total cost of production	$16.75
Net or stumpage value per 1,000 feet lumber scale	3.25

2. *Timber sold as saw logs, at* $10 *per* 1,000 *feet, log scale.*

	Per 1,000 board feet	
	Log scale	Lumber scale
Cutting and hauling logs	$6.25	$4.68
Net profit or stumpage value	3.75	2.82

In the above case the farmer would get more for his stumpage by selling sawed lumber.

Itemized costs.—The following figures show the range in costs of producing different kinds of woodlot products:

*Due to the fact that the lumber sawed out of a sound log nearly always exceeds the amount which the ordinary log scale designates as the contents of a log of its diameter and length.

Cost of Logging (Hardwoods)

	Cost per 1,000 board feet		
	Low	High	Average
Felling and cutting into logs	$ .75	$ 1.75	$ 1.25
Skidding (often omitted or included with hauling expenses, including swamping)	2.00	4.00	3.00
Hauling, 1 trip a day:*			
1,000 feet per load	2.00	4.00	3.00
800 feet per load	2.50	5.00	3.75
600 feet per load (average)	3.33	6.67	5.00
400 feet per load	5.00	10.00	7.50
200 feet per load	10.00	20.00	15.00
Loading	.....	1.00	.50

Manufacture and handling of lumber

	Cost per 1,000 board feet		
	Low	High	Average
Sawing and sticking	$ 3.00	$ 4.00	$3.50
Planing and finishing	1.00	2.00	1.50
Handling lumber in yard (including grading and loading)	1.00	1.00	1.00
Hauling, 1 trip a day* (1,000 board feet per load)	2.00	4.00	3.00
Loading on cars	.50	1.50	1.00

Cost of tie production

(For 7x9 ties; 6x8 ties one-fifth less)

	Costs per tie		
	Low	High	Average
Cutting and hewing ties	$ .12	$ .18	$ .15
Cutting and sawing ties (by portable mill)	.15	.20	.18
Hauling, 1 trip a day:*			
10 ties	.20	.40	.30
15 ties	.15	.30	.23
20 ties	.10	.20	.15
Loading on cars	.03	.05	.04

*For more than one trip a day divide these amounts by the number of trips per day. For less than one trip a day multiply these amounts by the number of days per trip.

Cost of pole and pile production

(35-feet length, 6 inches top)

	Costs per pole or pile		
	Low	High	Average
Cutting and trimming	$ .20	$ .40	$ .30
Hauling, 1 trip a day:*			
3 poles per load	.66	1.33	1.00
4 poles per load	.50	1.00	.75
5 poles per load	.40	.80	.60
Loading on cars	.05	.15	.10

Cost of producing material per cord and per rick

Firewood

	Cost per cord		
	Low	High	Average
Cutting (per stacked cord of 4-foot wood)	$ .75	$ 1.25	$ 1.00
Hauling, 1 trip a day	2.00	4.00	3.00

Handle bolts

(Hickory)

	Cost per rick		
	Low	High	Average
Cutting	$ 1.00	$ 1.50	$ 1.25
Hauling, 1 trip a day	2.00	4.00	3.00

Slack cooperage, veneer, and excelsior bolts

	Cost per rick (sticks 30 inches long)		
	Low	High	Average
Cutting	$ .50	$ 1.00	$ .75
Hauling, 1 trip a day	1.50	3.50	2.50

Pulpwood (peeled)

(Poplar, basswood, gum)

	Cost per rick (sticks 5 feet long)		
	Low	High	Average
Felling, peeling, and stacking	$ 1.25	$ 1.75	$ 1.50
Hauling, 1 trip a day	2.00	4.00	3.00

*For more than one trip a day divide these amounts by the number of trips per day. For less than one trip a day multiply these amounts by the number of days per trip.

Extract wood

	Cost per rick (160 cu. feet)		
	Low	High	Average
Cutting and splitting	$ 1.00	$ 1.50	$ 1.25
Hauling, 1 trip a day	2.50	4.50	3.50

Extract or tan bark

	Cost per cord of 2,240 lbs., dry
Cutting, peeling, and curing	$1.25 to $1.50
Loading	.50 to .50
Hauling, 1 trip haul	2.00 to 3.00

TABLE 13.—*Cost per 1,000 board feet of shipping different kinds of seasoned lumber at the freight rates given in the table.*

Kinds of wood	Thickness of lumber	Weight Per 1,000 bd. ft.	Freight rate in cents per 100 pounds[1] 1	2	3	4	5	6	7	8	9	10
			Cost per 1,000 board feet at above rates									
Hickory	1 inch and up	5,000	$0.50	$1.00	$1.50	$2.00	$2.50	$3.00	$3.50	$4.00	$4.50	$5.00
Oak, beech, maple, walnut	1 inch and up	4,000	.40	.80	1.20	1.60	2.00	2.40	2.80	3.20	3.60	4.00
Oak (quarter sawed)	¾ inch	3,200	.32	.64	.96	1.28	1.60	1.92	2.24	2.56	2.88	3.20
Oak (quarter sawed)	⅝ inch	2,700	.27	.54	.81	1.08	1.35	1.62	1.89	2.16	2.43	2.70
Oak (quarter sawed)	½ inch	2,200	.22	.44	.66	.88	1.10	1.32	1.54	1.76	1.98	2.20
Oak (quarter sawed)	⅜ inch	2,000	.20	.40	.60	.80	1.00	1.20	1.40	1.60	1.80	2.00
Ash and rock elm	1 inch and up	3,800	.38	.76	1.14	1.52	1.90	2.28	2.66	3.04	3.42	3.80
Soft elm and sycamore	1 inch and up	3,200	.32	.64	.96	1.28	1.60	1.92	2.24	2.56	2.88	3.20
Shortleaf pine	Boards	3,200	.32	.64	.96	1.28	1.60	1.92	2.24	2.56	2.88	3.20
Cypress	Boards	3,000	.30	.60	.90	1.20	1.50	1.80	2.10	2.40	2.70	3.00
Red gum	1 inch and up	3,300	.33	.66	.99	1.32	1.65	1.98	2.31	2.64	2.97	3.30
Red gum	¾ inch	2,500	.25	.50	.75	1.00	1.25	1.50	1.75	2.00	2.25	2.50
Red gum	⅝ inch	2,200	.22	.44	.66	.88	1.10	1.32	1.54	1.76	1.98	2.20
Red gum	½ inch	1,700	.17	.34	.51	.68	.85	1.02	1.19	1.36	1.53	1.70
Red gum	⅜ inch	1,300	.13	.26	.39	.52	.65	.78	.91	1.04	1.17	1.30
Sap gum	1 inch and up	3,100	.31	.62	.93	1.24	1.55	1.86	2.17	2.48	2.79	3.10
Sap gum	¾ inch	2,400	.24	.48	.72	.96	1.20	1.44	1.68	1.92	2.16	2.40
Sap gum	⅝ inch	2,000	.20	.40	.60	.80	1.00	1.20	1.40	1.60	1.80	2.00
Sap gum	½ inch	1,600	.16	.32	.48	.64	.80	.96	1.12	1.28	1.44	1.60
Sap gum	⅜ inch	1,250	.12	.25	.38	.50	.62	.75	.88	1.00	1.12	1.25
Tupelo	1 inch	3,000	.30	.60	.90	1.20	1.50	1.80	2.10	2.40	2.70	3.00
Tupelo	2 inches and up	3,200	.32	.64	.96	1.28	1.60	1.92	2.24	2.56	2.88	3.20
Poplar, chestnut, cherry and cottonwood	1 inch and up	2,800	.28	.56	.84	1.12	1.40	1.68	1.96	2.24	2.52	2.80
Poplar	¾ inch	2,100	.21	.42	.63	.84	1.05	1.26	1.47	1.68	1.89	2.10
Poplar	⅝ inch	1,600	.16	.32	.48	.64	.80	.96	1.12	1.28	1.44	1.60
Basswood	1 inch and up	2,600	.26	.52	.78	1.04	1.30	1.56	1.82	2.08	2.34	2.60
Buckeye	1 inch and up	2,500	.25	.50	.75	1.00	1.25	1.50	1.75	2.00	2.25	2.50

[1]For rates over 10 cents per 100, either use multiples of those given for from 1 to 10 cents, or add two or more of them together.

TABLE 14.—*Cost per 1,000 board feet, Doyle rule, of shipping green logs of different kinds of woods at freight rates given in table.*

Kinds of wood	Size of logs Diameter inside bark at small end Inches	Weight per 1,000 bd. ft. Doyle Scale	Freight rate in cents per 100 pounds[1] 1	2	3	4	5	6	7	8	9	10
			Cost per 1,000 board feet, Doyle scale, at above rates									
Ash	12	11,100	$1.11	$2.22	$3.33	$4.44	$5.55	$6.66	$7.77	$8.88	$9.99	$11.10
	18	7,700	.77	1.54	2.31	3.08	3.85	4.62	5.39	6.16	6.93	7.70
	24	6,600	.66	1.32	1.98	2.64	3.30	3.96	4.62	5.28	5.94	6.60
Basswood	12	9,500	.95	1.90	2.85	3.80	4.75	5.70	6.65	7.60	8.55	9.50
	18	6,600	.66	1.32	1.98	2.64	3.30	3.96	4.62	5.28	5.94	6.60
	24	5,600	.56	1.12	1.68	2.24	2.80	3.36	3.92	4.48	5.04	5.60
Beech	12	12,700	1.27	2.54	3.81	5.08	6.35	7.62	8.89	10.16	11.43	12.70
	18	8,900	.89	1.78	2.67	3.56	4.45	5.34	6.23	7.12	8.01	8.90
	24	7,500	.75	1.50	2.25	3.00	3.75	4.50	5.25	6.00	6.75	7.50
Cherry	12	10,500	1.05	2.10	3.15	4.20	5.25	6.30	7.35	8.40	9.45	10.50
	18	7,300	.73	1.46	2.19	2.92	3.65	4.38	5.11	5.84	6.57	7.30
	24	6,200	.62	1.24	1.86	2.48	3.10	3.72	4.34	4.96	5.58	6.20
Chestnut	12	12,600	1.26	2.52	3.78	5.04	6.30	7.56	8.82	10.08	11.34	12.60
	18	8,800	.88	1.76	2.64	3.52	4.40	5.28	6.16	7.04	7.92	8.80
	24	7,500	.75	1.50	2.25	3.00	3.75	4.50	5.25	6.00	6.75	7.50
Elm, soft	12	11,200	1.12	2.24	3.36	4.48	5.60	6.72	7.84	8.96	10.08	11.20
	18	7,800	.78	1.56	2.34	3.12	3.90	4.68	5.46	6.24	7.02	7.80
	24	6,600	.66	1.32	1.98	2.64	3.30	3.96	4.62	5.28	5.94	6.60
Gum, red	12	10,700	1.07	2.14	3.21	4.28	5.35	6.42	7.49	8.56	9.63	10.70
	18	7,500	.75	1.50	2.25	3.00	3.75	4.50	5.25	6.00	6.75	7.50
	24	6,300	.63	1.26	1.89	2.52	3.15	3.78	4.41	5.04	5.67	6.30

Hickory	12	14,700	1.47	2.94	4.41	5.88	7.35	8.82	10.29	11.76	13.23	14.70
	18	10,300	1.03	2.06	3.09	4.12	5.15	6.18	7.21	8.24	9.27	10.30
	24	8,700	.87	1.74	2.61	3.48	4.35	5.22	6.09	6.96	7.83	8.70
Maple, sugar	12	12,900	1.29	2.58	3.87	5.16	6.45	7.74	9.03	10.32	11.61	12.90
	18	9,000	.90	1.80	2.70	3.60	4.50	5.40	6.30	7.20	8.10	9.00
	24	7,600	.76	1.52	2.28	3.04	3.80	4.56	5.32	6.08	6.84	7.60
Maple, red	12	11,900	1.19	2.38	3.57	4.76	5.95	7.14	8.33	9.52	10.71	11.90
	18	8,300	.83	1.66	2.49	3.32	4.15	4.98	5.81	6.64	7.47	8.30
	24	7,100	.71	1.42	2.13	2.84	3.55	4.26	4.97	5.68	6.39	7.10
Oak, red	12	14,800	1.48	2.96	4.44	5.92	7.40	8.88	10.36	11.84	13.32	14.80
	18	10,300	1.03	2.06	3.09	4.12	5.15	6.18	7.21	8.24	9.27	10.30
	24	8,800	.88	1.76	2.64	3.52	4.40	5.28	6.16	7.04	7.92	8.80
Oak, white	12	14,400	1.44	2.88	4.32	5.76	7.20	8.64	10.08	11.52	12.96	14.40
	18	10,000	1.00	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00	10.00
	24	8,500	.85	1.70	2.55	3.40	4.25	5.10	5.95	6.80	7.65	8.50
Sycamore	12	12,000	1.20	2.40	3.60	4.80	6.00	7.20	8.40	9.60	10.80	12.00
	18	8,400	.84	1.68	2.52	3.36	4.20	5.04	5.88	6.72	7.56	8.40
	24	7,100	.71	1.42	2.13	2.84	3.55	4.26	4.97	5.68	6.39	7.10
Yellow poplar	12	8,800	.88	1.76	2.64	3.52	4.40	5.28	6.16	7.04	7.92	8.80
	18	6,100	.61	1.22	1.83	2.44	3.05	3.66	4.27	4.88	5.49	6.10
	24	5,200	.52	1.04	1.56	2.08	2.60	3.12	3.64	4.16	4.68	5.20
Walnut	12	11,900	1.19	2.38	3.57	4.76	5.95	7.14	8.33	9.52	10.71	11.90
	18	8,300	.83	1.66	2.49	3.32	4.15	4.98	5.81	6.64	7.47	8.30
	24	7,100	.71	1.42	2.13	2.84	3.55	4.26	4.97	5.68	6.39	7.10

[1]For rates over 10 cents per 100, either use multiples of those from 1 to 10 cents, or add two or more of them together.

TABLE 15.—*Shipping weights per stack of bolts, green and dry, of different lengths and diameters and different kinds of wood.*

	Diameter Inches	LENGTH OF BOLT—FEET								Weight per cu. ft.
		2½ (⅝ cd.)[1]	3 (¾ cd.)[1]	3½ (⅞ cd.)[1]	4 (1 cd.)[1]	4½ (1⅛ cd.)[1]	5 (1¼ cd.)[1]	5½ (1⅜ cd.)[1]	6 1½ cd.)[1]	
		WEIGHT PER STACK—POUNDS								
Ash, white										
Green	6	2,600	3,200	3,700	4,200	4,800	5,300	5,800	6,300	48.1
	9	2,800	3,300	3,900	4,400	5,000	5,500	6,100	6,600	
	12	2,900	3,400	4,000	4,600	5,100	5,700	6,300	6,900	
Air dry	6	2,300	2,800	3,200	3,700	4,200	4,600	5,100	5,600	42.1
	9	2,400	2,900	3,400	3,900	4,400	4,800	5,300	5,800	
	12	2,500	3,000	3,500	4,000	4,500	5,000	5,500	6,000	
Basswood										
Green	6	2,300	2,700	3,200	3,600	4,100	4,500	5,000	5,500	41.3
	9	2,400	2,800	3,300	3,800	4,300	4,700	5,200	5,700	
	12	2,500	2,900	3,400	3,900	4,400	4,900	5,400	5,900	
Air dry	6	1,400	1,700	2,000	2,300	2,600	2,800	3,100	3,400	25.8
	9	1,500	1,800	2,100	2,400	2,700	3,000	3,300	3,600	
	12	1,500	1,800	2,100	2,500	2,800	3,100	3,400	3,700	
Cottonwood										
Green	6	2,600	3,100	3,600	4,100	4,600	5,100	5,600	6,100	46.5
	9	2,700	3,200	3,700	4,300	4,800	5,300	5,900	6,400	
	12	2,800	3,300	3,900	4,400	5,000	5,500	6,100	6,600	
Air dry	6	1,500	1,800	2,100	2,400	2,700	3,000	3,300	3,600	27.3
	9	1,600	1,900	2,200	2,500	2,800	3,100	3,500	3,800	
	12	1,600	1,900	2,300	2,600	2,900	3,200	3,600	3,900	
Elm, rock and white										
Green	6	2,700	3,200	3,700	4,300	4,800	5,300	5,900	6,400	48.6
	9	2,800	3,400	3,900	4,500	5,000	5,600	6,100	6,700	
	12	2,900	3,500	4,000	4,600	5,200	5,800	6,300	6,900	
Air dry	6	1,900	2,300	2,700	3,000	3,400	3,800	4,200	4,600	34.6
	9	2,000	2,400	2,800	3,200	3,600	4,000	4,400	4,800	
	12	2,100	2,500	2,900	3,300	3,700	4,100	4,500	4,900	

Hickory, shagbark									
Green	6	3,500	4,200	4,900	5,600	6,300	7,000	7,700	8,400	63.8
	9	3,700	4,400	5,100	5,900	6,600	7,300	8,100	8,800	
	12	3,800	4,500	5,300	6,100	6,800	7,600	8,300	9,100	
Air dry	6	2,800	3,400	4,000	4,500	5,100	5,700	6,200	6,800	51.5
	9	3,000	3,600	4,100	4,700	5,300	5,900	6,500	7,100	
	12	3,100	3,700	4,300	4,900	5,500	6,100	6,700	7,300	

[1]Stacks are 4 feet in height by 8 feet long, made up of bolts of different sizes. Bolts 4 feet long make a standard cord, while shorter lengths make "short cords', and longer lengths a cord and over.

TABLE 16.—*Weights of piling and poles of different sizes, green and dry, for different kinds of wood; also weight per cubic foot of each.*

Length	White oak		Black oak		Sugar maple		Chestnut		White elm		Black gum		Increase with top diameter of 8 inches Per cent
	Green	Air dry	Green	Air dry	Green	Air dry	Green	Air dry	Green	Air dry	Green	Air dry	
Feet						WEIGHT—POUNDS							
20	610	470	610	440	550	430	540	300	480	340	440	350	15.3
25	770	590	770	550	690	530	670	370	600	430	550	450	15.4
30	920	700	920	660	820	640	810	440	710	510	660	530	15.6
35	1,080	820	1,080	770	960	750	940	520	840	600	770	620	15.7
40	1,580	1,200	1,590	1,140	1,410	1,100	1,390	760	1,230	880	1,130	920	12.3
45	1,780	1,360	1,790	1,280	1,590	1,240	1,560	860	1,390	990	1,270	1,030	11.9
50	1,980	1,500	1,980	1,420	1,770	1,370	1,730	950	1,540	1,090	1,410	1,140	12.3
						Weights per cubic foot used above—Pounds							
	67.2	45.0	62.5	47.6	55.9	43.4	54.8	30.2	48.6	34.6	44.7	36.2	

Top diameter 6 inches. Butt diameter 12 inches for piling 20 to 35 feet inclusive
14 inches for piling 40 to 50 feet inclusive.

Freight

Tables 13, 14, 15 and 16 should prove useful in calculating the costs of shipping different kinds of wood and classes of material.

6. Contracts and Supervision

In disposing of timber it is always best to have written contracts with purchasers or with the jobbers who are to deliver the material to purchasers. It is best, of course, to eliminate the jobber, if possible, and to deliver the material directly to the purchaser.

The following are the important items to be included in a contract with a purchaser where the products are to be cut and delivered by the farmer:

1. Kinds of woods and classes of materials, such as logs, bolts, poles, lumber, etc., and specifications in regard to forms, sizes, quality or grade, and quantity of different materials.
2. Price per unit of measurement, such as per 1,000 feet log scale or per cord, for each specified class of material, and time when payment is to be made. Payment should be made on delivery unless seller is protected by a bond on the purchaser.
3. Method of sale or delivery of the material.
4. Times, places, and methods of measurements of the material, including log rules, methods of allowing for defects, grading rules, etc., to be used.
5. Bond or other guarantee for faithful performance of contract.
6. Method of arbitration in case of disputes.

In case sale is to be made of standing timber the following additional stipulations should be provided for in the contract (From Bulletin 9 of the State of New York Conservation Commission). Many of these same stipulations can be used with jobbers in case contracts are made with them to cut and deliver products to purchaser:

1. Timber to be cut.

   Quantity and location of cutting.
   Sizes of trees to be cut or saved.
   Kinds of trees to be cut or saved.

   Provisions should be made for exceptions to the above clauses through marking of special trees to be saved or cut. If possible it is best to allow only those trees to be cut which are marked.

2. Provisions against waste.

   Height of stumps. This height should be specified, and ordinarily it should not exceed the stump's diameter.

   Utilization of tops. The smallest diameter to which material must be utilized should be stated. Material to be taken. It should be specified that all merchantable material be taken,—and the specific amount of defects which products may have and still be considered merchantable should be stated.

Fig. 19.—Woodlot almost ruined by fire in East Tennessee.

   Form in which timber is to be worked up. This should be specified if possible (thus, that certain sizes be converted to logs, others to poles, etc.)

   Materials to be used for roads, skidways, and other lumbering operations. It should be specified that only dead trees or certain inferior kinds be used.

3. Protection against damage.

   Care against injuring trees to be left.

   Provisions for protection from fire, and responsibility for fires occurring while on the work. Any fences removed, etc., to be replaced by substantial new fences.

4. Location of camps, mill site, etc.
   If these are used, provisions concerning them should be made.
5. Payments.
   Time—generally at least half should be paid as soon as trees are cut; and the rest before removal from land.
   Price per unit of measurement for each grade of material specified.
6. Faithful performance.
   Bond or other guarantee of at least one-quarter of the value of products included should be required. Penalties for violations of different clauses should be stipulated; in case the operator cuts trees that should be left or fails to remove trees marked for cutting, at double the ordinary price agreed on; for carelessly injuring trees to be left or other violations, a definite sum for each offense.
7. Duration of contract.
   The contract should stipulate when work is to begin and end, and that a certain amount is to be done within given limits of time. Repeated violations of any terms of the contract shall terminate it, with forfeiture of bond for faithful performance.

Supervision of cutting, logging, and scaling operations is very important; and a definite and clear contract, in writing, greatly simplifies this work. Measurements of material purchased should always be checked as provided for in the contract.

7. Co-operation with Neighboring Woodlot Owners

The chances of increasing profits from the sale of woodlot products can be greatly improved by intelligent coöperation with neighbors. The Forest Service, U. S. Department of Agriculture, in conjunction with various State organizations, plans to assist materially in developing this feature. Its agent will work coöperatively with the county agent and farmers in a given county to decide upon ways and means for profitable woodlot utilization in the county.

There are many different ways in which coöperation may be effected, only a few of which are suggested here:

1. Where favorable contracts for the sale of woodlot material can be made only in carload lots and the individual farmer has not

enough material to fill such contracts by himself, it will be wise for him to coöperate with his neighbors in supplying the necessary amounts.

2. Coöperation will be useful in securing information on favorable markets and prices for different classes of material.

3. Coöperative logging and manufacture of different classes of material, including the collective ownership and operation of logging outfits, sawmills, etc., may yield higher returns to the farmers than the present methods of sale.

Only by intelligent coöperation along some such lines will the woodlot owners, as a class, be able to get better values for the different classes of material grown in their woodlots.

Summary of Points to be Observed in Marketing

What the farmer should do in order to get the best returns from his woodlot sales may be summed up as follows:

1. Estimate the timber in the woodlot in terms of the most profitable classes of material.

2. Get as complete a knowledge as possible of local and outside markets for the different kinds of wood and classes of material contained in the woodlot. This should include the current prices and the specifications in regard to quality, size, and form. Write freely to wood-using firms for prices and specifications, using the directory of firms given in this report.

3. Estimate the cost of getting out the different kinds of trees and classes of material for the different possible markets; determine which markets will yield the highest net profits, and sell accordingly.

4. Never sell by the boundary or lump sum unless the timber has been carefully estimated.

5. Where there is uncertainty in regard to the amount of standing timber of a given kind in the woodlot, sell by log scale, cord, rick, or piece.

6. Always have a written contract with the purchaser, preferably supported by bond, stipulating in detail the form, size and quality or grade of material to be purchased by him, and the method of scaling, payments, etc.

7. Be thoroughly familiar with any deficiencies in the log rule to be used, especially in regard to underscaling of small logs, and figure on the price accordingly.

8. Coöperate freely with other woodlot owners in securing advantageous markets, and, if practicable, in logging and manufacture.

9. Be careful to use as much of every tree cut as can possibly be taken out at a profit.

10. Do not cut small, thrifty trees less than a foot or so in diameter on land to be held in woodlot, unless they are crowding more desirable individuals that are to be left.

HOW TO PREVENT THE DETERIORATION OF CUT WOODLOT PRODUCTS

It is often necessary or desirable to put off the delivery of logs, bolts, poles, etc., until some months after cutting, either in order to allow them to season or because a good sale can not be arranged at once. A great deal of the weight of fresh-cut products is due to the water they contain, and a few months' seasoning will often reduce this to a marked degree, the amount of reduction depending, of course, on the climate, the weather, and the exposure to sun and air. At the same time, unless preventive measures be taken, the products are sure to deteriorate through decay, insect attack, checking, or some other agency. A certain amount of deterioration is apt to take place in any case if the delivery is put off for some time; but the amount can be greatly reduced, and the saving in weight and increase in strength due to seasoning are more than enough to counterbalance any small deterioration which may occur in spite of the preventive measures.

Logs should never be allowed to remain long in the woods after cutting. As soon as possible they should be taken to a dry, well-aired, and unshaded area, and placed on skids well off the ground. The bark may be left on the logs and the ends should be coated with paint, creosote, or tar. This will not only assist in preventing decay but will also retard seasoning to some extent and thus keep the logs from checking badly.

Poles should be peeled and hauled or dragged to a place free from débris or rank vegetation and freely exposed to sun and wind. There they should be rolled upon skidways not less than 18 inches high, so that no part of them will rest on the ground. There should be only one layer of poles on each skidway. When ties are cut it is usually cheapest and most desirable to haul them, unseasoned, directly to

the railroad and there pile them according to the specifications furnished by the tie buyer.

Cordwood should be stacked in loose piles in a sunny, well-aired and well-drained place free from rank vegetation. Two sticks on the ground running the length of the pile will keep it from contact with the soil and thus prevent decay in the lower layers.

DIRECTORY OF WOOD-USING FIRMS*

1. Sawmills in Tennessee Using Saw Logs

(Which cut for the most part over 1,000,000 board feet a year)

County	*Town*	*Firm name*
Benton	Camden	J. B. Reed
Blount	Cades Cave	Sam Spak
Blount	Razar	John C. Lambert
Blount	Maryville	Lee Grindstaff
Blount	Maryville	Maryville Lumber Company
Blount	Townsend	Little River Lumber Company
Bradley	McDonald	James Cooper
Bradley	Cleveland	Cleveland L. & M. Co.
Carter	Roan Mountain	T. H. Whitehead
Carter	Hampton	Pittsburg Lumber Company
Cheatham	Ashland City	Burkholder Bros.
Claiborne	Clairfield	Valley Creek & Co.
Coffee	Tullahoma	M. R. Campbell
Cumberland	Westel	Troller Lumber Co.
Davidson	Nashville	John B. Ransom & Co.
Davidson	Nashville	Cherokee Lumber Company
Davidson	Nashville	Lieberman, Loveman & O'Brien
Davidson	Nashville	Davidson, Hicks & Greene Co.
Dickson	Dickson	W. P. Branson & Sons Lumber Co.
Dickson	McEwen	S. W. Taylor & Co.
Dickson	Pardue	Albert E. Pardue
Dickson	Dickson	M. R. Campbell
Dickson	Decherd	C. E. Murry
Dyer	Trimble	Trimble Lumber Company
Dyer	Dyersburg	North Vernon Lumber Company
Dyer	Tiger Tail	Tiger Tail Mill & Land Co.
Dyer	Mengelwood	Mengel Box Co.
Fentress	Harriman	J. H. Watts
Fentress	Allardt	E. C. Ross & Sons
Fentress	Lake	Logan Finch
Fentress	Allardt	Otto Fritzoche
Fentress	Allardt	H. Whealton & Son
Fentress	Wilder	Davidson, Hicks & Greene Co.
Franklin & others	Nashville	Southern Lumber Co.
Gibson	Rutherford	A. A. Tray
Gibson	Humboldt	B. C. Jarrell & Co.
Giles	Pulaski	Pulaski Rim & Spoke Co.
Greene	Greeneville	F. J. Brown

*It is not claimed that this directory is complete. It represents only those firms whose names the Forest Service has in its files, some of which may now be out of business.

County	*Town*	*Firm name*
Greene	Greeneville	John Heilman Lumber Co.
Greene	Greene County	Patterson Lumber Co.
Grundy	Tracy City	Sam Wener
Hamilton	Chattanooga	Cedar Products Co.
Hamilton	Chattanooga	The Loomis & Hart M. Co.
Hamilton	Chattanooga	McLean Lumber Co.
Hamilton	Chattanooga	Williams & Sons Lumber Co.
Hamilton	Chattanooga	Berry Lumber & Stove Co.
Hardeman	Toone	Wanerkent Co.
Hawkins	Rogersville	Chas. D. Jarvis
Henry	Paris	W. Soger
Hickman	Hickman County	S. H. Hinson
Hickman	Only	J. C. Burchard
Hickman	Hampshire	G. W. Stanley & Sons
Houston	Stewart	Mitchell & Dunagan
Humphreys	Hurricane Mills	Jas. J. Anderson
Humphreys	Hurricane Mills	H. D. Estes
Jackson	Difficult	Cassetty Bros.
James	Georgetown	L. A. Caster
James	Apison	J. H. Reed
Johnson	Butler	Geo. W. Kite
Johnson	Butler	W. F. Burton
Johnson	Pottsville	Tennessee Lumber Manufacturing Co.
Knox	Straw Plains	C. H. Duignan
Knox	Knoxville	D. M. Rose & Co.
Knox	Knoxville	Vestal Lumber & Manufacturing Co.
Knox	Knoxville	Knoxville Sawmill Co.
Lake	Phillippy	Chas. D. Phillippy Merc. & Lumber Co.
Lake	Ridgely	Hannington Bros. Lumber Co.
Lawrence	Lewis	U. S. Slak Lumber Co.
Lawrence	Ethridge	W. W. Lumber Co.
Lawrence	Ethridge	J. C. Keplinger
Lawrence	Henryville	J. E. Stone & Co.
Lawrence	Iron City	Forsyth Bros. Lumber Co.
Lewis	Hampshire	W. M. Taggin
Lewis	Hohenwald	S. H. Hinson
Lincoln	Fayetteville	Williams Lumber Co.
Loudon	Lenoir City	R. M. Callaway
McMinn	Riceville	W. P. Pellis
McNairy	Guys	A. C. Wilson
Macon	Red Springs	W. D. Parkhurst
Madison	Jackson	Young and Cutsinger
Marion	South Pittsburg	Eagle Pencil Co., or Hudson Lumber Co., Jan. 1, 1912
Maury	Mt. Pleasant	C. A. Long
Monroe	Tellico Plains	Tellico River Lumber Co.

County	*Town*	*Firm name*
Monroe	Mt. Vernon	W. J. Norris (?)
Morgan	Harriman	J. G. Cooper
Morgan	Harriman	Tennessee Stave & Lumber Co.
Obion	Polk	Hale Bros.
Obion	Fulton	Swain-Karmile Lumber Co.
Perry	Lobelville	W. J. Bates
Perry	Linden	Jones & Woolfolk Co.
Polk	Jennya	J. B. Taylor
Polk	Cincinnati	Marion Timbering Co.
Polk	Bonnie	Albert Crumly
Polk	Conasauga	Alaculsy Lumber Co.
Putnam	Monterey	Johnson Bros.
Putnam	Monterey	Woodcliffe Lumber Co.
Putnam	Cookeville	Cookeville Veneer Co.
Putnam	Baxter	J. A. Isbell
Rhea	Spring City	Penn. Coal & Lumber Co.
Roane	Oakdale	James Newhouse
Roane	Rockwood	John Molyneaux
Robertson	Cedar Hill	Cedar Hill Lumber Co.
Rutherford	Walterhill	Gulf Red Cedar Works
Rutherford	Murfreesboro	R. P. Wilson
Scott	Norma	New River Lumber Co.
Scott	Lexington	E. B. Spotswood & Son
Scott	Elk Valley	Douglass & Walkey Co.
Sevier	Trundles X R'ds.	George Brown
Sevier	Trundles X R'ds.	W. J. Sauk
Sevier	Sevierville	Twin River Lumber Co.
Sevier	Sevierville	A. J. Hupp
Shelby	Memphis	Mossman Lumber Co.
Shelby	Memphis	I. M. Darnell Son Co.
Shelby	Memphis	Anderson-Tully Co.
Shelby	Memphis	Bennett Hardwood Lumber Co.
Shelby	Memphis	Anchor Sawmill Co.
Shelby	Memphis	Russe & Burgess, Inc.
Shelby	Memphis	R. J. Darnell, Inc.
Shelby	Memphis	O. S. Gladden
Shelby	Memphis	Green River Lumber Co.
Shelby	Memphis	Nickey & Sons Co.
Shelby	Memphis	Nickey Bros. Hardwood Lumber Co.
Shelby	Memphis	McLean Hardwood Lumber Co.
Shelby	Memphis	Mahannah Lumber Co.
Shelby	Memphis	Memphis Veneer Lumber Co.
Shelby	Mf's, 10	Mfg. Sawmill Co.
Shelby	Memphis	Florence Pump and Lumber Co.
Shelby	Memphis	Moore & McFerren
Shelby	Memphis	J. V. Stimson Hardwood Co.

County	*Town*	*Firm name*
Shelby	Memphis	May Bros.
Shelby	Onabaska	Philip A. Ryan Lumber Co.
Shelby	Memphis	McCollum Bros.
Shelby	Memphis	Tschew Lumber Co.
Shelby	Memphis	Hartzell Handle Co.
Shelby	Millington	Woods Lumber Co.
Sullivan	Abindgdon, Va.	Burkman, Wright & Mock Co.
Sullivan	Blountville, Tenn.	E. R. & J. T. Fey
Sullivan	Blountville, Tenn.	R. E. Houser
Sullivan	Johnson City	Dickey Lumber Co.
Sullivan	Bristol	Peter McCain Lumber Co.
Sullivan	Bluff City	Black Mountain Land Co.
Tipton	Covington	W. S. Nayes (Nayes Lumber Co.)
Unicoi	Unicoi	Clear Fork Lumber Co.
Unicoi	Flag Pond	T. G. Salts
Unicoi	Unicoi	W. C. N. Goodman
Union	Speedwell	Morris Williams
Union	Carryton	W. T. Gibbs
Warren	McMinnville	Burroughs-Ross-Colville Co.
Warren	McMinnville	McMinnville Spoke & Lumber Co.
Washington	Johnson City	American Cigar Box Lumber Co.
Washington	Johnson City	Harris Manufacturing Co.
Washington	Johnson City	Tenn. Lumber & Veneer Corp'n
Washington	Telford	Sam Light
Washington	Garbers	F. D. Hill
Wayne	Allens Creek	Clendenin Bros.
Wayne	Clifton	J. J. Halder
Wayne	Waynesboro	R. L. Morrow
Weakly	Dresden	Dresden Spoke Co.
Wilson	Lebanon	Gulf Red Cedar Works

2. Vehicle Stock Plants and Dealers

(Which purchase hickory logs, bolts, and billets, some white oak, and a little red oak)

Town	*Firm name*
Algood	Pennock-Walter Manufacturing Co. (spokes)
Bristol	Beveridge & Taylor (spokes)
Brownsville	Byrn Bros. (spokes)
Centerville	Buckeye Spoke Co.
Chattanooga	Hickory Spoke Works (spokes)
Dickson	M. R. Campbell (spokes)
Dresden	Dresden Spoke Works (spokes)
Dyersburg	W. N. Clayton (spokes)
Dyersburg	Imperial Wheel Co.
Halls	W. N. Clayton (spokes)

Town	*Firm name*
Halls	Halls Spoke Co. (spokes) (also at Spring City)
Harrison	N. C. Blanchard (spokes)
Hohenwald	The Mitchell Wheel Co.
Humboldt	Foltz Manufacturing Co. (handles and spokes)
Jackson	Weis & Lesh Mfg. Co. (spokes, skewers, and butcher's blocks)
Livingston	J. C. Bilbrey Spoke Co. (spokes)
McMinnville	Burroughs, Ross, Colville Co. (handles & spokes)
Manchester	Manchester Manufacturing Co. (wagon stock)
Memphis	Kelsey Wheel Co.
Memphis	Gillette Bros.
Memphis	Memphis Carriage & Wagon Supply Co. (stock)
Memphis	Memphis Pioneer Pole & Shaft Co. (stock)
Memphis	Weis & Lesh Manufacturing Co.
Millington	D. C. Jennings (spokes)
Monterey	Standing Stone Manufacturing Co. (spokes)
Monterey	A. L. Saylor (spokes)
Morrison	Philpot Lumber Co. (vehicle stock)
Nashville	Hermitage Spoke Co.
Nashville	Rock City Spoke Co.
Newbern	Inman Bros. (vehicle stock)
Polk (Obion County)	Henry Blevins (spokes and handles)
Pulaski	Pulaski Rim & Spoke Co.
Smithville	E. J. Evans & Son (spokes)
Sparta	Sparta Spoke Factory
Tullahoma	M. R. Campbell (hubs and spokes)
Tullahoma	Campbell & Dann Mfg. Co. (wagon stock)
McKinney, Ky.	Columbia Singletree Co. (also spokes and neck-yokes)
Owensboro, Ky.	Owensboro Wheel Co.
Owensboro, Ky.	Carriage Woodstock Co.
Paducah, Ky.	Lack Singletree Co.
Paducah, Ky.	J. W. Little (spokes)
Scottsville, Ky.	J. W. Allen (spokes)

3. Tie, Pole, and Pile Producers and Buyers

Town	*County*	*Firm name*
Athens		Tennessee Tie & Lumber Co.
Bluff Point	Hickman	J. A. Ray & Son
Camden	Benton	J. C. Durden & Sons
Crab Orchard	Cumberland	Wilson & Wheeler
Crab Orchard	Cumberland	C. F. Willoughby
Chattanooga	Hamilton	Chattanooga Pole Co.
Chattanooga	Hamilton	Doran & Co.
Crossville	Cumberland	Cumberland Tie Co.

Town	*County*	*Firm name*
Dickson	Dickson	F. W. Crow
Jackson	Madison	Mississippi Valley Tie Co.
Johnson City	Washington	Valley Tie & Lumber Co.
Johnson City	Washington	Clinchfield Tie & Lumber Co.
Knoxville	Knox	Blue Ridge Tie Co.
Knoxville	Knox	Standard Tie Co.
Livingston	Overton	Valley Tie & Lumber Co.
Memphis	Shelby	Ayer & Lord Tie Co.
Nashville	Davidson	Davidson & McBride (poles)
Nashville	Davidson	Joyce-Watkins Co.
Nashville	Davidson	Nashville Tie Co.
Saltillo	Hardin	J. M. Gibbs
Stewart	Houston	Mitchell & Dunagan
Bowling Green, Ky.		Ayer & Lord Tie Co.
Louisville, Ky.		American Creosoting Co.
Louisville, Ky.		W. J. Hughes & Sons Co.
Louisville, Ky.		Ohio Valley Tie Co.
Paducah, Ky.		Ayer & Lord Tie Co.
Paducah, Ky.		Bartee Tie Co.
Paducah, Ky.		Paducah Pole & Timber Co.
Paducah, Ky.		A. B. Smith Lumber Co. (piling and poles)
Chicago, Ill.		Chicago Mill & Lumber Co. (black locust poles, posts, and piling)
Chicago, Ill.		Lake Superior Piling Co.
St. Louis, Mo.		Berthold & Jennings Lumber Co. (piling, poles, and ties)
St. Louis, Mo.		Geo. M. Griffin (piling and poles)
St. Louis, Mo.		Hearne Timber Co.

In addition to the above, apply to local and outside railroads and electric roads, to telegraph and telephone companies, and to dock construction companies in large cities, for prices and specifications on ties, poles, and piling.

4. Veneer Mills

(Using logs and bolts)

Town	*Firm name*
Chattanooga	Consignees Favorite Box Co. (gum, pine, maple)
Cookeville	Cookeville Veneer Co. (gum, poplar, and maple)
Dandridge	G. B. and J. C. Williams (pine, poplar)
Dyer	Dyer Fruit Box Mfg. Co. (gum, poplar, elm, and sycamore)
Graysville	Graysville Fruit Package Co.
Greenfield	Ward-Kent Co. (gum)
Johnson City	American Cigar Box Lumber Co. (poplar)

Town	*Firm name*
Johnson City	Tennessee Veneer Co.
Knoxville	Knoxville Basket & Crate Co. (gum, maple, poplar)
Knoxville	Knoxville Veneer Co.
Memphis	Anderson-Tully Co. (gum, maple, poplar, cottonwood)
Memphis	Memphis Veneer & Lumber Co (white and red oak)
Sharon	J. E. Edwards (gum)
Trezevant	Ware & Goodwin (gum)
Trimble	Sharon Veneer Co. (gum)
Burnside, Ky.	Chicago Veneer Co. (oak, poplar)
Hickman, Ky.	Mengel Box Co. (gum)
Louisville, Ky.	Louisville Veneer Mills (oak and poplar)
Louisville, Ky.	Kentucky Veneer Works (gum and poplar)
Louisville, Ky.	Southern Veneer Manufacturing Co. (white oak)
Paducah, Ky.	Paducah Box & Crate Co. (gum)
Cincinnati, Ohio	Maley, Thompson & Moffet Co. (oak)
Cincinnati, Ohio	Talbert-Zoller Lumber Co. (oak)
Evansville, Ind.	Evansville Dimension Co. (gum, oak, elm)
Indianapolis, Ind.	Indiana Veneer & Lumber Co. (oak)
Indianapolis, Ind.	Indianapolis Sawed Veneer Co. (oak)
Indianapolis, Ind.	National Veneer & Lumber Co. (oak)
Indianapolis, Ind.	Gemmer Veneer & Lumber Co. (oak)
New Albany, Ind.	Wood Mosaic Co. (oak)
New Albany, Ind.	Roberts & Conner (oak, walnut, cherry, etc.)
Cairo, Ill.	Singer Manufacturing Co. (walnut, oak, gum)
Mound City, Ill.	Portsmouth Veneer & Panel Co. (oak,poplar,gum)
St. Louis, Mo.	St. Louis Box & Basket Co.(oak,gum,cottonwood)
Sheffield, Mo.	Penrod Walnut & Veneer Co. (walnut and oak)

5. Slack Cooperage Plants

(Using Logs and Bolts)

County	*Town*	*Firm name*
Tennessee		
Bedford	Nashville	Welch Stave & Heading Co. (oak, etc.)
Davidson	Shelbyville	Caldwell Stave Co. (elm, beech, oak)
Dickson	White Bluffs	Hunter & Ashton (oak)
Dickson	White Bluffs	Graham Stave Co. (oak)
Dickson	White Bluffs	Turnbull Stave Co. (oak)
Dickson	Spencers Mill	Luther Bros. (oak)
Dickson	Cumb. Furnace	J. T. Peeler (oak)
Dickson	Burns	M. J. Lampley (oak)
Dickson	Vanleer	Frank H. Stone (oak)
Dyer	Dyersburg	Dyersburg Hoop Co. (elm hooks)

County	*Town*	*Firm name*
Tennessee		
Dyer	Dyersburg	Fields-Rupe Stave Co. (gum, elm, maple, ash, cottonwood, sycamore)
Dyer	Mengelwood	Mengel Box Co. (gum, cottonwood)
Fayette	Moscow	Moscow Cooperage & Lbr. Co. (gum)
Franklin	Sherwood	Gayer Lime & Mfg. Co. (all kinds)
Hickman	Bon Aqua	W. M. Dudley & Son
Henry	Paris	Paris Lumber Co. (gum, poplar, sycamore)
Houston	Erin	V. R. Harris (oak)
Houston	Erin	E. W. Raucher (oak, gum, etc.)
Houston	Stewart	Mitchell & Dunagan (oak)
Lake	Tiptonville	Park-Davis Stave Co. (gum, elm, ash, cottonwood, sycamore)
Lawrence	Napier	J. J. Jensen & Co. (oak, etc.)
Lawrence	Loretta	Green Bros. (oak, hickory, hoops)
Lincoln	Elora	C. E. Murry (oak)
Maury	Mt. Pleasant	Tennessee Cooperage Co. (oak, chestnut, poplar)
Montgomery	Palmyra	J. W. Wickam (oak hoops)
Montgomery	Louise	E. D. Lewis & Son (oak, etc.)
Obion	Rives	Obion Cooperage Co. (oak, maple, beech, poplar gum)
Obion	Obion	H. Forcum & Co. (all kinds)
Rutherford	La Vergne	J. S. Griggs (elm and chestnut hoops)
Shelby	Memphis	Memphis Stave Mfg. Co. (gum, cotton- (Anderson-Tulley Co.) wood, etc.)
Shelby	Memphis	Tennessee Hoop Co. (elm hoops) (Anderson-Tully Co.)
Shelby	Memphis	W. P. Hall Stave Co. (cottonwood)
Smith	Rome	J. T. Green & Highers (hoops, elm, etc.)
Stewart	Indian Mount	W. E. McGregor (oak)
Williamson	Jingo	Advance Stave & Lumber Co. (oak)
Williamson	McMinnville	Welling Bros. (elm hoops)
Wilson	Watertown	S. H. Flippen & Co. (elm hoops)
Kentucky		
Allen	Scottsville	J. D. Read & Co.
Allen	Hopkinsville	Forbes Manufacturing Co.
Allen	Paducah	Sherrill-King Mill & Lumber Co.
Fulton	Hickman	A. P. Mills
Illinois		
	Metropolis	H. Rampendahl, Jr., & Co. (gum, etc.)
	Mound City	Reed Manufacturing & Box Co.

County	*Town*	*Firm name*
Missouri		
	New Madrid	New Madrid Hoop & Lumber Co.
	New Madrid	Modern Cooperage Co.
	Caruthersville	Caruthersville Cooperage Co.
	Cape Girardeau	George McBride

6. Pulp and Excelsior Plants

(Using bolts)

Town	*Firm name*
Bristol, Tenn.	Columbian Paper Co.
Buena Vista, Va.	Columbian Paper Co.
Burnside, Ky.	Burnside Excelsior Co.
Cleveland, Tenn.	Cleveland Excelsior Co.
Jackson, Tenn.	Patton-Black Mfg. Co. (willow, poplar, cottonwood)
Knoxville, Tenn.	Knoxville Coffin Co. (basswood and buckeye)
Knoxville, Tenn.	Knoxville Excelsior Mattress Co. (poplar, pine)

7. Tanbark and Extractwood Plants and Users

County	*Town*	*Firm name*
Blount	Maryville Tenn.	Sprinkle & Son
Blount	Walland	The Schlosser Leather Co.
Campbell	Jellico	Elk Valley Tannery
Carter	Watauga	Beggs & Coff
Cocke	Newport	Unaka Tanning Co.
Coffee	Tullahoma	J. N. Tipps
Davidson	Nashville	Marsh Collar & Harness Co.
Green	Greenville	The Greenville Tannery
Hamblen	Morristown	Morristown Oak Leather Co.
Hamilton	Chattanooga	Robert Schloze Tannery
Hamilton	Chattanooga	Union Tanning Co.
Knox	Knoxville	Southern Extract Co.
Lincoln	Fayetteville	W. J. Landers & Co.
Roane	Harriman	American Oak Leather Co.
Sumner	Gallatin	A. L. Fry
Union	Maynardsville	L. M. Wallace
Washington	Johnson City	Union Tanning Co.
Washington	Johnson City	Watauga Tannery
	New Decatur, Ala.	American Oak Leather Co.
	Middlesboro, Ky.,	Union Tanning Co.

8. Handle Factories

(Using logs and bolts—mostly hickory and some ash, white oak, and dogwood)

Town	*County*	*Firm name*
Baxter	Putnam	J. A. Isbell (hickory)
Caney Springs	Marshall	Turner-Day-Woolworth Handle Co.
Cookeville	Putnam	E. J. Greggory Handle Works (hickory)
Chattanooga	Hamilton	Dixie Logging Tool Co. (hickory)
Crockett	Obion	Turner-Day-Woolworth Co. (hickory)
Dickson	Dickson	A. H. Leathers Handle Co. (hickory)
Fowlkes	Dyer	Fowlkes Handle Co. (hickory)
	Hickman	S. H. Hinson (hickory)
Jackson	Madison	The Anchor Block Mills (hickory)
Lynnville	Giles	Turner-Day-Woolworth Handle Co.
Memphis	Shelby	The Hartsell Handle Co. (hickory)
Memphis	Shelby	Turner-Day-Woolworth Handle Co.
Nashville	Davidson	Reuther Scranton Handle Co.
Nashville	Davidson	Nashville Spoke & Handle Co. (hickory)
Nashville	Davidson	Turner-Day-Woolworth Handle Co.
Sequatchie	Marion	Sequatchie Handle Works (hickory)
South Berlin	Marshall	Turner-Day-Woolworth Handle Co. (hickory)
Kentucky		
Bowling Green	Warren	Turner-Day-Woolworth Handle Co.
Princeton	Caldwell	Turner-Day-Woolworth Handle Co.
Scottsville	Alden	Turner-Day-Woolworth Handle Co.
Missouri		
Caruthersville		Geo. C. Peattie
Dexter		I X L Handle Manufacturing Co.
Poplar Bluff		Hanna & Young Handle Co.
Illinois		
Cairo		Clark-Danforth Handle Co.
Cairo		Wm. Haas & Sons

9. Miscellaneous

(Using logs)

Town	*Firm name*
Algood, Tenn.	Algood Column Co. (small poplar logs)
Brownsville	E. B. Chester (hickory and ash)
Elizabethton	Empire Chair Co. (logs)
Jackson	Weis & Lesh Mfg. Co. (hickory and beech logs—butcher blocks and skewers)
Johnson City	Harris Mfg. Co. (oak logs)
Knoxville	Nickerson Mfg. Co. (small poplar logs)

Town	*Firm name*
Memphis	Anchor Boat Oar Co. (select ash & hickory logs)
Memphis	Oil Well Supply Co. (ash and hickory logs)
Memphis	E. G. Willingham (hickory)
Sparta	Sparta Colonial Column Co. (small poplar logs)

10. SHUTTLE BLOCK MILLS

(Using dogwood and persimmon)

Town	*County*	*Firm name*
Algood, Tenn.	Putnam	Speyer Lumber Co.
Brownsville	Haywood	E. B. Chester
Cookeville	Putnam	Dorman & High
Dickson	Dickson	J. Murchison
Harriman	Madison	Harriman Shuttle Block Co.
Hohenwald	Lewis	Hohenwald Block Mills
Jackson	Madison	Anchor Block Mills Co.
Maryville	Madison	Randolph Shuttle Block Mill
Memphis	Shelby	Anchor Boat Oar Co.
Decatur, Ala.		J. W. Reese

11. USERS OF CEDAR

Town	*Firm name*
Chapel Hill	Cumberland Cedar Mills
Chattanooga (Alton Park)	Cedar Products Co.
Chattanooga	Hudson Lumber Co. (pencil stock), South Pittsburg, Tenn.
Christiana	Wm. Foerster & Co.
College Grove	Cox & Maney (also at Murfreesboro)
Johnson City	American Cigar Box Lumber Co.
Lebanon	Gulf Red Cedar Works (also at Waterhill)
Lebanon	Thos. J. Dye & Son (cedar posts)
Lewisburg	American Lead Pencil Co.
Lewisburg	Houston & Liggett
Murfreesboro	R. P. Wilson Red Cedar Works
Murfreesboro	W. T. Bruer & Son (cedar products) (also at Nashville)
Nashville	F. & O. Cedar Works
Nashville	Myers Manufacturing Co.
Nashville	J. B. Ransom & Co.
Nashville	J. P. Meredith Cedar Co. (also at Lebanon)
Shelbyville	Cumberland Cedar Mills (pencils)
Shelbyville	Cumberland Cedar Works
Shelbyville	Landers & Co. (cedar posts, poles, pencils)
Shelbyville	Ransom & Frierson (cedar posts, poles, pencils)
Smyrna	W. T. Bruer & Son (cedar products)
Smyrna	W. B. Coleman (cedar posts)
Smyrna	Pruitt & Hibbett (cedar posts)

12. BUYERS OF BLACK WALNUT LOGS

State	*Town*	*Firm name*
Alabama	Mobile	N. W. Dunlap (exporter)
Illinois	Belvidere	National Sewing Machine Co.
	Cairo	Singer Manufacturing Co.
	Chicago	R. S. Bacon Veneer Co.
	Kankakee	Foley & Williams
	Rockford	Illinois Sewing Machine
	Chicago	C. L. Willey
	East St. Louis	East Saint Louis Walnut Co.
Indiana	Fort Wayne	Hoffman Bros. Co.
	Indianapolis	Indiana Veneer & Lumber Co.
	Indianapolis	The Talge Mahogany Co.
	Lawrenceburg	Batesville Lumber & Veneer Co.
Kentucky	Lexington	Headley Lumber Co. (exporters)
Maryland	Baltimore	Williamson Veneer Co.
Louisiana	New Orleans	Schut & Kiehn (exporters)
Missouri	East St. Louis	East Saint Louis Walnut Co.
	Kansas City	Pickerel Walnut Co.
	St. Louis	Penrod Walnut & Veneer Co.
North Carolina	Lenoir	Lenoir Veneer Co.
Ohio	Cincinnati	The Ohio Veneer Co., 2624 Colrain Ave.
	Dayton	H. C. Hossafores
	Piqua	George W. Hartzell
Pennsylvania	Philadelphia	A. H. Fox Gun Co.
Tennessee	Concord	P. W. Bevins
	Knoxville	Vestal Lumber & Mfg. Co.
	Knoxville	R. J. Denton
	Memphis	Penrod-Jurden & McCowan
	Memphis	May Brothers
	Memphis	A. C. Franck
	Nashville	J. B. Ransom & Co.

13. TENNESSEE TIGHT COOPERAGE PLANTS AND DEALERS

(Using logs, bolts, and billets of white and red oak)

CAMPBELL COUNTY

Town	*Firm name*	*Main office*
Cupp	Wilkerson & Early	
Morley	Valley Creek Lumber Co	Rochester, N. Y.
Westbourn	A. R. Humble	Somerset, Ky.
	C. G. Steele	London, Ky.

CARROLL COUNTY

Huntingdon	F. Priest & Son	
Westport	J. H. McCall (idle)	

Town	*Firm name*	*Main office*
	CUMBERLAND COUNTY	
Crossville	Jos. Deters & Son	
	DAVIDSON COUNTY	
Nashville	I. F. McLean	McLean Mfg. Co.
Nashville	Chess & Wymond Co.	Louisville, Ky.
	DICKSON COUNTY	
Dickson	R. K. Nicks	
Dickson	Interstate Cooperage Co.	719 Hickox Bldg. Cleveland, Ohio
Tenn. City R. D. 2.	W. A. Franklin	
Vanleer	F. H. Stone	
	DYER COUNTY	
Dyersburg	N. W. Calcutt Co.	
	GIBSON COUNTY	
Eaton	Harlan-Morris Co.	Trenton, Tenn.
Rutherford	Barton Bros. & Co.	Harlan-Morris
Trenton	Harlan-Morris Co.	
Trenton	Gibson County Gin Co.	
	GRUNDY COUNTY	
Coalmont	Christian Kopp	Altamont, Tenn.
Altamont	I. F. McLean	
	HAMILTON COUNTY	
Chattanooga	Interstate Cooperage Co.	
Chattanooga	Chattanooga Stave & Cooperage Co.	Consol. Cooperage Co., Inc.
	HAYWOOD COUNTY	
Brownsville	F. H. Valterman	
Shepp	F. H. Valterman	
Stanton	F. H. Valterman	
	HENDERSON COUNTY	
Juno	J. H. Holmes	
	HENRY COUNTY	
	L. W. McGehee (idle)	Hazel, Ky.

HICKMAN COUNTY

Town	*Firm name*	*Main office*
(Near Centerville)	A. L. Hayes & Co.	Centerville
	I. F. McLean (?)	
Goodrich	J. W. Simpson (idle)	Waverly
Littlelot	T. B. Tatum	
Lyles	W. I. Tatum (idle)	

HOUSTON COUNTY

Stewart	J. R. Jones & Co.	
Erin, R. D. 1	W. J. Clark	

HUMPHREYS COUNTY

McEwen	Patterson & Cowen	
Tennessee City	S. W. Taylor & Co.	
(Dickson County)		
Waverly	E. E. Wollam	
Waverly	Ridings & Turner	

LAKE COUNTY

Ridgeley	N. W. Calcutt	Dyersburg

MCNAIRY COUNTY

Ramer	Harlan-Morris Co.	Trenton

MADISON COUNTY

Jackson	W. H. Coleman Co.	

MAURY COUNTY

Mt. Pleasant	Tennessee Cooperage Co. (idle)	

MORGAN COUNTY

Deer Lodge	Rugby Stave & Lumber Co.	

OVERTON COUNTY

Hanging Limb	Welch Stave & Heading Co.	
Livingston	J. C. Brilbrey Spoke Co.	
Livingston	I. F. McLean	
Livingston	J. R. Hogue	
Rickman, R. D.	Smith & Marlow	
Livingston	J. G. Eastland	
	Laurel Creek Stave & Lumber Co.	
Wirmingham	William Parks	

PUTNAM COUNTY

Town	*Firm name*	*Main office*
Cookeville	J. W. Scott	
Monterey, R. D.	Johnson Bros.	

SCOTT COUNTY

Huntsville	W. H. Potter	
Oneida	Crescent Stave Co.	

SEQUATCHIE COUNTY

	Frazier & Hunt	Tatesville

SHELBY COUNTY

Memphis	Chickasaw Cooperage Co.	
Memphis	Interstate Cooperage Co.	719 Hickox Bldg. Cleveland, Ohio
Memphis	Kennedy Heading Co.	

STEWART COUNTY

Big Rock	Harris & Cherry	

WEAKLEY COUNTY

Dresden	Shannon & Loyd	
Greenfield	Stout Bros.	
Sharon	Coats, Malone & Co.	

WILLIAMSON COUNTY

Franklin, R. D.	I. F. McLean	

14. Wood-using Firms in Tennessee Using Sawed Lumber

(Chiefly of firms consuming over one-half million feet a year)

Town	*Firm name*
Alton Park (near Chattanooga)	Chattanooga Bottle & Glass Mfg. Co. (boxes)
Athens	Athens Planing Mill
Athens	Athens Table Mfg. Co.
Athens	J. A. Royle
Bristol	Bristol Coffin Co.
Bristol	Bristol Door & Lumber Co.
Bristol	Paxton Lumber Co.
Bristol	Peter-McCain Lumber Co.
Bristol	Stone-Huling Lumber Co.
Camden	Hudson & Durdin
Centreville	T. S. Colley's Sons

Town	*Firm name*
Chattanooga	Chattanooga Box & Lumber Co.
Chattanooga	Acme Box Co.
Chattanooga	Chattanooga Wagon Co.
Chattanooga	Chattanooga Lumber Co.
Chattanooga	Consignees Favorite Box Co.
Chattanooga	Chattanooga Coffin & Casket Co.
Chattanooga	Chattanooga Furniture Co.
Chattanooga	King-Baxter Lumber Co.
Chattanooga	Hunt Spring Bed Co.
Chattanooga	The Odorless Refrigerator Co.
Chattanooga	Tennessee Coffin & Casket Co.
Chattanooga	Union Lumber Co.
Chattanooga	Lookout Planing Mill.
Clarksville	Sewanee Lumber Co.
Cleveland	Barnes Manufacturing Co.
Cleveland	Cleveland Coffin & Casket Co.
Cleveland	W. S. Mulne (furniture)
Cleveland	Marshall Planing Mill
Clinton	The T. H. Leinart Co.
Columbia	Vaughn Manufacturing Co.
Cookeville	Crawford, Lowe & Qualls
Decherd	S. P. Bruner & Son
Dickson	Dickson Planing Mill Co.
Dyer	Hearn Lumber Co.
East Chattanooga	H. J. Judd & Co. (curtain poles)
Elizabethton	Empire Chair Co.
Elizabethton	Star Planing Mill
Franklin	W. J. Beasley
Franklin	Craig Lumber Co.
Franklin	Southern Bros.
Gallatin	S. D. Simpson & Son
Greeneville	Greeneville Chair Co.
Greeneville	Greeneville Furniture Co.
Harriman	Stowers Lumber & Mfg. Co.
Harriman	Harriman Mfg. Co. (agricultural implements)
Harriman	Dame Mantel Co.
Hohenwald	Hohenwald Planing Mill & Brick Mfg. Co.
Huntington	Wilder & Leach
Jackson	Budde-Lindsay Mfg. Co. (fixtures)
Jackson	Southern Seating & Cabinet Co.
Johnson City	Sella Lumber & Mfg. Co.
Johnson City	Exum Furniture Co.
Johnson City	Harris Mfg. Co. (also agric. implements)
Johnson City	Tenn. Box. Co. (low-grade pop. logs and lumber)
Knoxville	American Mantel Mfg. Co.
Knoxville	C. B. Atkins Co. (furniture)

Town	*Firm name*
Knoxville	Broadway Mfg. Co.
Knoxville	Chavannes Lumber Co.
Knoxville	F. B. Cooley & Son
Knoxville	Holston Box & Lumber Co.
Knoxville	Hall & Donahue Coffin & Casket Co.
Knoxville	H. L. Ingles Mantel Co.
Knoxville	Knoxville Coffin Co.
Knoxville	Knoxville Basket & Crate Co.
Knoxville	Knoxville Lumber Co.
Knoxville	The Proctor Furniture Co.
Knoxville	D. M. Rose Lumber Co.
Knoxville	Ross Lumber Co.
Knoxville	Tennessee Mantel Manufacturing Co.
Knoxville	Whittle Trunk & Bag Co.
Lafayette	Brown-Hunt Co.
Lafayette	Freeman Mill Co.
Lebanon	Wilson County Planing Mill Co.
Lenoir City	Electric Lumber Co.
Lewisburg	Sanders Bros. & Co.
Lexington	T. Edwards
Loretto	Meiers, Augustin & Co.
Lynnville	Lynnville Lumber Co.
McMinnville	McMinnville Spoke & Lumber Co.
Madisonville	J. R. Burllason
Madisonville	Madisonville Chair Co.
Martin	City Lumber Co.
Maryville	Bittle & Hufstetler Co.
Maryville	Cherokee Manufacturing Co.
Maryville	Southern Coffin & Casket Co.
Maryville	G. N. Mize
Memphis	Anderson Tully Co. (boxes)
Memphis	Cole Manufacturing Co.
Memphis	Dugger & Goshorn Co. (agric. implements)
Memphis	Darnell-Taenzer Lumber Co.
Memphis	Florence Pump & Lumber Co.
Memphis	George O. Friedel Lumber & Manufacturing Co.
Memphis	James & Graham Wagon Co.
Memphis	Jorgsen Bennett Manufacturing Co.
Memphis	Lee Lumber Co.
Memphis (south)	Larkin Co. of America (chairs)
Memphis	Memphis Coffin Co.
Memphis	Memphis Hardwood Flooring Co.
Memphis	Moore & McFerren
Memphis	Wabash Screen Door Co.
Memphis	Walden Braxton Manufacturing Co.
Memphis	York Manufacturing Co.

Town	*Firm name*
Monterey	Monterey Planing Mill Co.
Morristown	I. P. Fort Co.
Morristown	Johnson-Baker-Donaldson Chair Co.
Murfreesboro	Perkins-Crichlow Co.
Murfreesboro	Williams Bros.
Nashville	The Davidson, Hicks & Greene Co.
Nashville	Home Building & Manufacturing Co.
Nashville	George Moore & Sons
Nashville	G. O. Kirkpatrick & Sons
Nashville	Lieberman, Loveman & O'Brien (boxes)
Nashville	Merchants Wire-bound Box Co.
Nashville	Nashville Hardwood Flooring Co.
Nashville	Southern Lumber & Manufacturing Co.
Nashville	Standard Furniture Co.
Nashville	Tennessee Oak Flooring Co.
Nashville	White Trunk & Bag Co.
Newcomb	Newcomb Manufacturing Co.
Newport	McCabe Lumber Co.
Portland	Portland Planing Mill Co.
Pulaski	J. M. Patterson & Son
Pulaski	T. W. Pittman & Co.
Sevierville	Sevierville Planing Mill Co.
Sparta	Carter & Potter
Sparta	East Sparta Planing Mill Co.
Springfield	Springfield Planing Mill Co.
Tellico Plains	Tellico River Lumber Co.
Tracy	Samuel Weaner
Tullahoma	The Anderson-Stegall Manufacturing Co.
Tullahoma	Greenfield-Talbot Furniture Co.
Viola	Mansfield-Bonner Co.
Waynesboro	Buchanan & Gower

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THE RESOURCES OF TENNESSEE

A MAGAZINE DEVOTED TO THE DESCRIPTION, CONSERVATION AND DEVELOPMENT OF THE RESOURCES OF TENNESSEE

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OCTOBER, 1917

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Looking down on the Eastern Highland Rim from the Cumberland Plateau

Structure of the Waynesboro Quadrangle with Special Reference to Oil and Gas*

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By Hugh D. Miser

INTRODUCTION

In the early nineties and in 1915 gas in small quantities was struck at shallow depths in two wells at Iron City, in the southeast corner of the Waynesboro quadrangle. This discovery, together with reported surface showings of oil and gas and with the search for new oil and gas fields, has raised the question in the minds of many people as to the possibility of the presence of commercial quantities of these substances in this quadrangle. A detailed study of the geology of the quadrangle, conducted in 1913 and 1914 by the writer with the assistance in 1913 of Dr. N. F. Drake, Dr. Bruce Wade, and Mr. Olaf P. Jenkins, revealed the presence of several domelike or anticlinal folds, a type of structure that is one of the conditions favorable for the accumulation of oil and gas. A description of these folds and a discussion of the possibilities of finding oil and gas in paying quantities are given in this report.

TOPOGRAPHY

The Waynesboro quadrangle is a little west of south-central Tennessee and includes nearly all of Wayne County and narrow strips of the adjoining counties of Hardin, Perry, Lewis, and Lawrence. It also includes a narrow strip of Lauderdale County, Alabama. It embraces a part of the Highland Rim, which is a dissected plateau. The part so embraced in the quadrangle varies in different places

*The field work in this area was done under a coöperative agreement between the State Geological Survey and the U. S. Geological Survey, the latter bureau being represented by Mr. Miser. This paper is published by permission of the Director of the U. S. Geological Survey. A preliminary report by Dr. N. F. Drake was published in 1914 in vol. 4, no. 3 of the Resources of Tennessee. The detailed report is now in course of preparation by the present writer.

from 750 to 1,050 feet above sea level and is extensively dissected by stream valleys which are usually 100 to 300 feet deep below the plateau surface. The principal streams as well as many of the smaller ones are shown on the accompanying map.

The area is sparsely populated. The chief occupations are iron mining, lumbering, and agriculture.

The Florence & Sheffield Branch of the Louisville & Nashville Railroad traverses the southeast corner of the quadrangle passing through St. Joseph and Iron City. Another branch of this railroad runs from Iron City through Wayland Springs and West Point to Pinkney. The Tennessee Western Railroad runs from Iron City to Collinwood. The Centerville Branch of the Nashville, Chattanooga & St. Louis Railway enters the northeast corner of the area and extends as far as Allens Creek. Tennessee River, which crosses the northwest corner of the area, is navigated by river steamers.

GEOLOGY

STRATIGRAPHY

The exposed rocks of the Waynesboro quadrangle are all of sedimentary origin and consist predominantly of limestone, though beds of shale, chert, sandstone, gravel, and sand are found. They are of Ordovician, Silurian, Devonian, Carboniferous, Cretaceous, and Quaternary age. Their sequence and general character and distribution are given in the following generalized section:

Generalized section of rocks in the Waynesboro quadrangle

QUATERNARY SYSTEM

Alluvium, 35+ feet thick; gravel and loam in narrow strips along most streams.

Terrace deposits, 35+ feet thick; gravels overlain by loam; occurs in patches along Tennessee and Buffalo rivers.

CRETACEOUS SYSTEM

UPPER CRETACEOUS SERIES

Eutaw formation, 50 feet thick; red fossil-wood-bearing sand on ridges in southwest quarter of quadrangle.

Tuscaloosa formation, few feet to 150 feet thick; gravel on ridges in all parts of quadrangle but in greatest quantity in southwest quarter.

CARBONIFEROUS SYSTEM

MISSISSIPPIAN SERIES

St. Louis limestone, 50 to 200 feet thick; cherty, gray limestone overlain almost everywhere by thick, residual mantle of clay and chert; has larger surface distribution than any other formation.

Fort Payne chert, 100 to 200 feet; composed of dense, black chert and platy, gray shale but mainly of dark, calcareous chert that changes on slopes to soft, yellow, platy, porous chert; contains some crinoidal limestone in southeast part of quadrangle; exposed on hill slopes in all parts of area.

Ridgetop shale, 0 to 90+ feet thick; composed of dark, platy shale in northern and western parts of quadrangle; beds of apparently the same age in the southeast part are green siliceous shale and thin and thick beds of cherty gray crinoidal limestone. Maury glauconic member, which in places is platy shale and in others sandstone, is at base; dark, phosphatic nodules common; 0 to 2 feet thick.

DEVONIAN SYSTEM

UPPER DEVONIAN SERIES

Chattanooga shale, 0 to 37 feet thick; black shale from a feather edge to 22 feet thick; widely distributed but less so than the basal member, the Hardin sandstone, which is composed of rather fine-grained, gray, massive sandstone and which is from 0 to 15 feet thick.

MIDDLE DEVONIAN SERIES

Pegram limestone, 0 to 5⅝ feet thick; granular, gray, crinoidal limestone in small area on Mill Creek near Forty-eight post office.

LOWER DEVONIAN SERIES

Linden formation, 0 to 55 feet thick; gray, granular limestone in places; in others cherty, sandy limestone; present only in northwest part of quadrangle.

SILURIAN SYSTEM

Decatur limestone, 0 to 60 feet thick; massive, light-gray to bluish-gray, granular to dense limestone; present only on west side of quadrangle.

Brownsport formation

Lobelville shaly limestone member, 0 to 62 feet thick; shaly limestone containing large coral fauna; present only on west side of quadrangle.

Bob crystalline limestone member, 0 to 35 feet thick; massive, crystalline, gray limestone; present only in northern and western parts of quadrangle.

Beech River shaly limestone member, 0 to 84 feet thick; shaly, fossiliferous, cherty limestone; present only in northern and western parts of quadrangle.

Wayne formation

Dixon early limestone member, 0 to 45 feet thick; earthy limestone; red near Clifton but greenish gray to the east and southeast; exposed in all except southwest parts of quadrangle.

Lego limestone member, 0 to 36 feet thick; compact pinkish and bluish-gray limestone; exposed in all except southwest parts of quadrangle.

Waldron clay member, 0 to 5 feet thick; fossiliferous, indurated, gray though less often pink clay, near middle of which is thin, persistent limestone layer; exposed in all except southwest parts of quadrangle.

Laurel limestone member, 0 to 32 feet thick; sompact, pinkish and bluish-gray limestone; exposed in all except southwest parts of quadrangle.

Osgood earthy limestone member, 0 to 17 feet thick; thin-bedded, earthy limestone; red at and near Clifton and Iron City but gray elsewhere; exposed in all except southwest parts of quadrangle.

Brassfield limestone, 1 to 25 feet thick; even-bedded, finely crystalline, gray limestone containing glauconite; exposed in northern and southeastern parts of quadrangle.

ORDOVICIAN SYSTEM

UPPER ORDOVICIAN SERIES

Fernvale formation, 20 to 40 feet thick; the lower half is phosphatic gray limestone; the upper, green shale. Exposed in northern and southeastern parts of quadrangle.

Arnheim limestone, 0 to 3 feet thick; cherty, gray limestone; exposed only at Clifton.

Leipers limestone, 0 to 75+ feet thick; dark-bluish, fossiliferous limestone and a less amount of brown shale; exposed on Shoal Creek northeast of Wayland Springs.

MIDDLE ORDOVICIAN SERIES

(Cathey's limestone not known to be present.)

Bigby limestone, 0 to 45 (?) feet thick; light-gray and dark-gray, fossiliferous limestone; not exposed but found in wells at Iron City.

Hermitage formation, 80+ feet thick; even-bedded, dark-bluish limestone in thin layers alternating with about same amount of dark, fissile shale; exposed only in northwest part of quadrangle.

STRUCTURE

General features.—The rocks of the Waynesboro quadrangle have been deformed but little since their deposition in a nearly horizontal position. Although they lie upon the southwest flank of the Nashville dome they have no marked dip to the southwest. They have been bent into numerous gentle but irregular anticlinal and synclinal folds. The general structure of the quadrangle is a dome whose highest part, as a whole, is in the center. The principal anticline which crosses the center of the quadrangle, has a northeastward trend parallel with that of the folds in the Appalachian region in East Tennessee and other states.

The rocks of the quadrangle are comparatively free from faults; only three have been observed.

Mode of representation.—The structure of the rocks is represented on the accompanying map, which shows contour lines on the deformed upper surface of the Chattanooga shale as determined by the outcrops of that shale and overlying formations. The Chattanooga, although thin, is one of the most widely exposed formations in the quadrangle and is one of the most easily recognized. The map does not necessarily represent exactly the structure of the other formations because most of them are not present everywhere and because even where they are present their thicknesses are not uniform. The relief of the deformed surface in any portion of the quadrangle is shown by the contour lines on the map, which represent intervals of 50 feet, the numbers showing elevations above the sea.

Anticlines and domes.—The Collinwood anticline, named from Collinwood which is near its axis, is by far the most pronounced fold in the Waynesboro quadrangle. It extends from near Powells Mill in the southwestern part of the area, northeastward across the center of the quadrangle, terminating in the northeast corner of Wayne County and the northwest corner of Lawrence County. It is irregular in shape, and the more prominent irregularities are here mentioned. One prong near Ovilla trends eastward, another prong that is southwest of Allens Creek trends northward, and another, though lower, prong which is later described as the Wayland Springs anticline runs southeastward to the southeast corner of the quadrangle. The highest part is southwest of Allens Creek; there the elevation of the Chattanooga shale exceeds 800 feet above sea

level. This part also contains the oldest exposed rocks. These rocks belong to the Fernvale formation and are exposed along Blowing Spring Branch, a tributary of Forty-eight Creek. The dip away from the axis is in most places between 25 and 40 feet to the mile, but the northwest and southwest slopes of the anticline merge into minor anticlinal folds.

The Wayland Springs anticline which might be called a prong of Collinwood anticline is in the southeast part of the quadrangle. It trends in a southeast direction, merging to the northwest with the Collinwood anticline and terminating to the southeast near St. Joseph. Its highest part is a low nearly circular domelike area on Shoal Creek and the lower course of Factory Creek just northeast of Wayland Springs. This part is steepest on the northeast side where the dip is 100 feet in half a mile. The oldest rocks revealed by erosion on its crest belong to the Leipers limestone. Another but smaller dome occupies the crest of the anticline 3 miles south of west of West Point. The oldest rocks exposed on it belong to the Wayne formation. Two wells drilled at Iron City on the southwest slope of the anticline obtained a small flow of gas from the Bigby and Hermitage formations. Descriptions of these wells are given on pages 207-212.

The Waynesboro anticline is L-shaped and culminates in two small domes, one of which is about a mile north of Waynesboro and the other about 1½ miles west of that place. Both domes are about the same height. Erosion has, however, cut deeper into the one than the other. The Osgood earthy limestone and higher members of the Wayne formation are the oldest exposed rocks on the crest of the dome north of Waynesboro, and the Chattanooga shale is the oldest exposed formation on the crest of the one west of that place.

A small dome, attaining an elevation of over 650 feet above sea level, is on the divide between Hardin and Flat Gap creeks, on the west side of the quadrangle. The oldest strata exposed on its crest belong to the Dixon earthy limestone member of the Wayne formation.

The Eagle Creek anticlines are south-southeast of Clifton and are between that town and Eagle Creek. Both are small but the one to the south is the higher. It trends in a northeast direction parallel with the course of Eagle Creek, which flows in a narrow syncline along the southeast side of the anticline. The other anticline trends

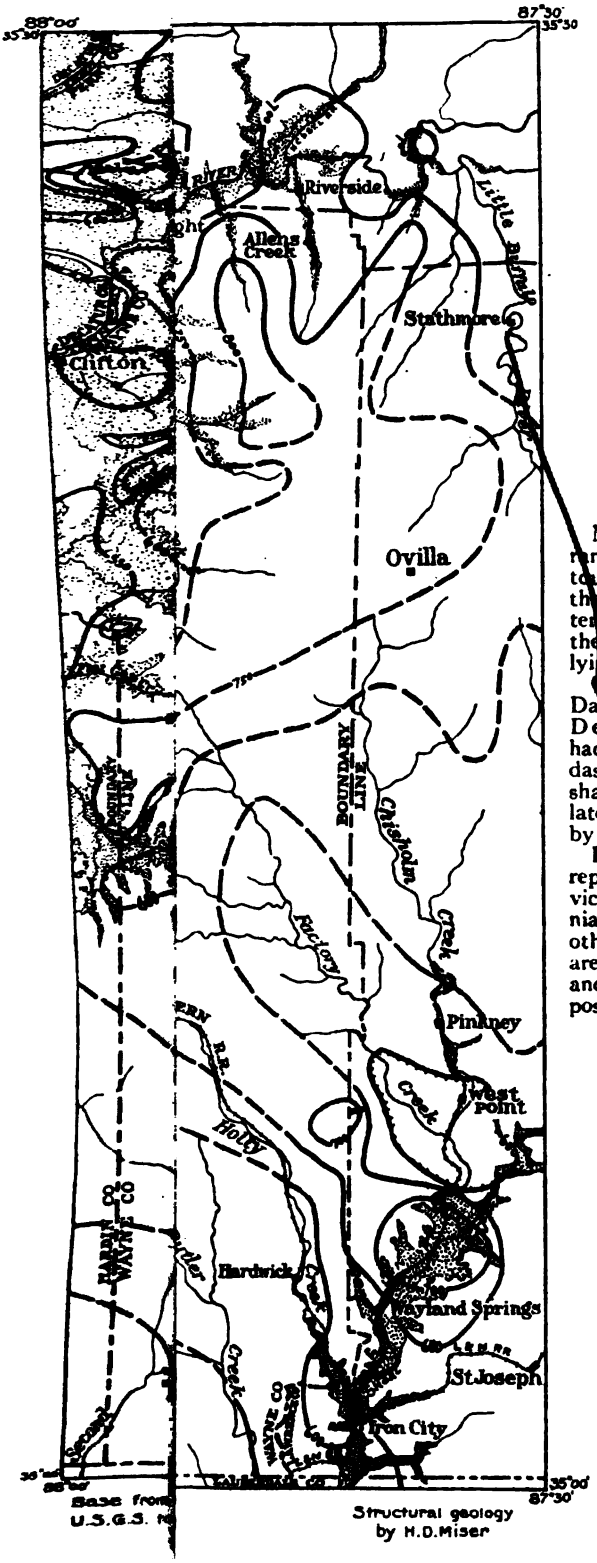

PLATE 1.

Map of Waynesboro quadrangle showing structure contours on the upper surface of the Chattanooga shale as determined by the outcrops of the Chattanooga and overlying formations.

Contour interval 50 feet. Datum is mean sea level. Depression contours are hachured. Contours are dashed where Chattanooga shale is deeply buried beneath later rocks. Faults are shown by heavy lines.

Dotted portions of map represent areas in which Ordovician, Silurian, and Devonian rocks are exposed; the other portions represent areas in which Carboniferous and Cretaceous rocks are exposed.

westward and is separated from the one to the south by a syncline. The oldest formation exposed on the crest of the higher anticline is the Hermitage while the oldest on the crest of the lower one is the Fernvale.

The crest of a dome or anticline, as indicated by excellent rock exposures along the right bank of Tennessee River, is located at the old cement furnace at the west edge of Clifton. This furnace is just west of the area shown on the accompanying map. A normal fault with a downthrow of about 75 feet on the west side apparently runs in a nearly northward direction across the crest a short distance west of the cement plant. East of the fault the Hermitage is the oldest exposed formation, while to the west of it the Brassfield limestone is the oldest. Owing to a lack of exposures north and south of this locality the extent of the dome or anticline in these directions is not known.

Three anticlinal folds are near Beech Creek in the northwest part of the quadrangle. One of these is on the west edge of the quadrangle north of the mouth of Beech Creek; it trends almost east and west. The second is just north of Little Beech Creek. It trends in a northeastward direction; is triangular in outline and reveals the Hermitage formation on its crest, which is occupied by the valley of a small tributary of Little Beech Creek. The third, of irregular shape, is on the divide between Beech Creek and Buffalo River, 4 miles west of south of Flatwoods. The highest part, which is at the east end, has been cut into by a small tributary of Beech Creek. The Hermitage is the oldest exposed formation on this tributary.

A number of other anticlines which are lower than the ones described above occur in the northern and western parts of the quadrangle. Among them are one just north of Martins Mill, one 3 miles north-northwest of Houston, one 2½ miles northeast of Clifton, one 6 miles nearly due east of Clifton, and one 3 miles east-northeast of Riverside. These are all shown on the accompanying map.

Basins.—Several basin-like or synclinal folds in the upper surface of the Chattanooga shale occur in different parts of the quadrangle, but most of them are along the larger streams. The relation of the structure to the drainage is more fully discussed under the next heading.

Relation of structure to drainage.—A striking relation between the drainage and the folds in the rocks is apparent from the accompanying map, but would probably be more so from a structure map with a much smaller contour interval than 50 feet. The drainage, which is radial from the central part of the quadrangle, is away from the axis of the Collinwood anticline, the principal anticline which, as above indicated, extends from near Powells Mill in a northeastward direction to the vicinity of Allens Creek and Strathmore. The divide between the drainings on the two sides of the anticline therefore coincides very closely with the axis of the anticline.

Many of the larger streams, including Factory, Indian, Hardin, Eagle, Beech, and Forty-eight creeks and Green and Buffalo rivers, flow partly or wholly in synclinal folds that occur on either side of the Collinwood anticline. On the other hand, Shoal Creek takes an unexpected course across a comparatively large dome, and Chisholm and Holly creeks do not bear any relation to the minor anticlinal or synclinal folds. As many of the larger streams occupy synclinal folds, most of their tributaries flow toward the axes of the synclines and thus with the dip of the rocks. The grade of the streams in many places is the same or nearly the same as the downstream dip of the rocks.

From the above it is obvious that the structure has in great measure controlled the courses of the streams.

OCCURRENCE OF OIL AND GAS

The Chattanooga and Ridgetop shales contain a small quantity of oil which may be detected by the odor of fresh pieces of the shale but they probably do not contain over a few gallons to the ton. The oil could be recovered only by mining the shale and distilling the oil from it, but its recovery would probably not be economical under present conditions unless the yield were well over 20 gals. to the ton of shale. Samples of the Chattanooga shale obtained at Bakers and Newsom, Tenn., near Nashville, contained from none to 9.1 gallons of oil and from 835 to 1,916 cubic feet of gas per short ton.[1] This shale near Hamburg, Tenn., about 15 miles west of the Waynesboro quadrangle, contains so much bituminous matter, including oil, that a large

[1]Ashley, G. H., Oil resources of black shales of the eastern United States: U. S. Geol. Survey Bull. 641, pp. 316-319, 1917.

pile of the fresh shale dumped at the edge of Tennessee River near that place caught on fire from spontaneous combustion and burned for about two months.*

Showings of oil and gas on the surface and in shallow wells are reported at a number of places in the northwest part of the quadrangle but the most noteworthy occurrences thus far discovered are in two wells at Iron City.

In 1892 or 1893 a well was drilled at that place to a depth of 315 feet where gas was struck. The flow of gas was so strong that it blew the drill out of the well, but it decreased enough in 2 or 3 days for the well to be capped without difficulty. The gas was burned at times for 2 or 3 months; but, as its utilization was not undertaken on account of the financial panic at the time, a poplar plug was driven deep into the well to prevent the escape of gas.† At the time of the writer's visit in 1914 the strong sulphur water that was encountered at a depth of 200 feet was being used for drinking. The sulphur water probably comes from near the base of the Bigby limestone and the gas probably came from the Hermitage formation.

A second well, known as the Seavy-Lull well, was begun in December, 1914, 300 feet west of the above-described well, but owing to a crooked hole it was abandoned March 1, 1915, after it had been drilled to a depth of 261 feet. Mr. E. L. Lull, a mining engineer, who had charge of the drilling, reports that an estimated flow of 5,000 cubic feet of gas per 24 hours with a rock pressure of about 20 pounds per square inch was obtained from the Bigby limestone at a depth of 182 to 205 feet. He also reports a trace of gas and oil from the Hermitage formation at and near the bottom of the well. A practically complete set of cuttings from the well was carefully saved by Mr. Lull and sent to the writer for examination. A few fragmentary fossils found in the cuttings were examined and reported upon by Mr. E. O. Ulrich. The record of the well follows:

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*Bowers, Paul C., An interesting case of spontaneous combustion: The Resources of Tennessee, vol. 6, pp. 37-40, 1916.

†This information was furnished the writer by the late Captain H. P. Seavy who was a prominent citizen of Iron City.

RECORD OF SEAVY-LULL WELL, IRON CITY, TENN.

[Engineer in charge, E. L. Lull; drillers, J. R. Wilson and F. P. Miller. Drilling begun December 11, 1914; well discontinued March 1, 1915. Elevation of top of well 565 feet above sea level.]

Age and formation		Sample No.	Depth (in feet) at which sample was obtained	Author's description of samples	Description of rocks and remarks by engineer in charge
Quaternary	Alluvium				0-8 feet, alluvium
SILURIAN	Wayne formation, Laurel limestone member	1	8-10	Finely crystalline, gray limestone with pink spots, making limestone pinkish gray	Very hard limestone
		2	10-12	Same as sample No. 1	
		3	12-14	Red and greenish, compact, somewhat earthy limestone	
	Wayne formation, Osgood earthy limestone member	4	14-18	Red, compact, somewhat earthy limestone	Very hard, shaly, red limestone
		5	18-20	Same as sample No. 4	
		6	20-23		Very hard red limestone; cherty layers
		7	23-26		Very hard brownish limestone; so called spathite
	Brassfield Limestone	8	26-29.5	Compact, light-gray limestone with glauconite grains	Very hard, siliceous limestone; little or no iron
	Brassfield Limestone or Fernvale Formation	9	29.5-33	Red limestone	Soft, red shale
ORDOVICIAN	Fernvale formation	10	33-35	Buff, calcareous, argillaceous material, probably shale	Green shale, probably phosphatic
		11	35-37.5	Greenish-gray, slightly phosphatic, sandy, argillaceous, highly calcareous material, probably impure limestone	Green shale
		12	37.5-39	Soft, calcareous, gray shale	
		13	39-44	Dark-gray, very impure limestone, containing much fine quartz sand	Green shale, probably arenaceous

Age and formation	Sample No.	Depth (in feet) at which sample was obtained	Author's description of samples	Description of rocks and remarks by engineer in charge
ORDOVICIAN — Fernvale formation	14	44-48	Slightly phosphatic, rusty, earthy limestone	Hard, brownish-yellow limestone
	15	48-51.5	Yellowish clayey, calcareous rock; probably shale with limestone streaks	
	16	51.5-55	Compact, light-gray, fossiliferous, slightly phosphatic limestone	Hard, gray limestone
	17	55-57	Light-gray, compact, phosphatic limestone	
ORDOVICIAN — Leipers limestone	18	57-62	Gray calcareous shale	Soft, blue limestone and clay
	19	62-65	Gray earthy, calcareous material, probably shale	Blue limestone
	20	65-70	Gray earthy, calcareous material. It is calcareous shale or very earthy limestone	Very hard blue limestone
	21	70-72	Gray fossiliferous, slightly phosphatic limestone and gray shale	
	22	72-75	No sample	Fairly hard, blue limestone; shaly layers
	23	75-90	Dark-gray shale and finely crystalline, slightly phosphatic, fossiliferous gray limestone	Fairly hard, blue limestone
	24	90-100	Slightly phosphatic, dark-gray compact, fossiliferous limestone	
	25	100-105	Drab-colored, calcareous shale, containing some gypsum	Very hard, blue limestone
	26	105-110	Dark-gray, slightly phosphatic, fossiliferous limestone, containing some clayey matter	
	27	110-115	Same as sample No. 26	

Age and formation	Sample No.	Depth (in feet) at which sample was obtained	Author's description of samples	Description of rocks and remarks by engineer in charge
ORDOVICIAN — Bigby limestone (?)	28	115-120	Light-gray, slightly phosphatic limestone and dark-gray arenaceous shale	Soft blue shaly limestone
	29	120-125	Same as sample No. 28; fossils examined by E. O. Ulrich, who reports them as "probably older than Catheys"[a]	Fairly hard, impure, blue crystalline limestone
	30	125-130	Fine-grained, dark-gray, slightly phosphatic, fossiliferous limestone containing some argillaceous matter	
	31	130-135	Brown, slightly phosphatic, fossiliferous, somewhat earthy limestone; grain of medium size	Fairly hard, yellowish fine-grained, fossiliferous, crystalline limestone
	32	135-139	Brown, slightly phosphatic, earthy material, may be earthy ferruginous limestone	Hard, yellowish, fine-grained, fossiliferous, crystalline limestone
	33	139-143	Gray, slightly phosphatic, fossiliferous limestone of medium grain; some material contains considerable clayey matter	Very hard, coarse, fossiliferous, crystalline, grayish limestone
	34	143-145.5	Like sample No. 35, except no fossils were seen	Very hard, fine-grained, crystalline, grayish limestone
	35	145.5-150	Light-gray, moderately crystalline, slightly phosphatic, fossiliferous limestone	
	36	150-154	Light-gray and dark-gray, moderately crystalline, slightly phosphatic, fossiliferous limestone	Very hard, coarse, crystalline, grayish limestone
	37	154-160	Dark-gray, finely crystalline, slightly phosphatic, fossiliferous limestone and some shale	Very hard, bluish limestone

[a]The Catheys limestone where present in Tennessee is between the Bigby and Leipers limestones.

Age and formation	Sample No.	Depth (in feet) at which sample was obtained	Author's description of samples	Description of rocks and remarks by engineer in charge
ORDOVICIAN — Bigby limestone	38	160-165	Dark-gray, slightly phosphatic, calcareous, fossiliferous shale. Fossils examined by Ulrich	Very hard, bluish limestone
	39	165-170	Dark-gray, finely crystalline, phosphatic, fossiliferous limestone and black shale. Fossils examined by Ulrich	Very hard, bluish limestone; probably arenaceous
	40	170-173	Dark-gray, finely crystalline, slightly phosphatic limestone and slightly calcareous black shale. Fossils examined by Ulrich	Very hard, probably arenaceous bluish limestone; trace of gas
	41	173-179	Limestone like that in sample No. 40. Fossils examined by Ulrich	Very hard, fine-grained crystalline, bluish limestone; trace of gas
	42	179-182	Dark-gray, finely crystalline, slightly phosphatic limestone and slightly calcareous, black shale. Contains some pyrite	Very hard, fine-grained, crystalline, bluish-gray limestone; trace of gas
	43	182-184	No sample	Very hard, fine-grained, crystalline, bluish-gray limestone containing pyrite. A strong flow of water highly charged with various salts, hydrogen sulphide, and probably natural gas. Estimated flow of water 500 gallons per hour rising 150 feet in well. Estimated flow of gas 5,000 cubic feet per 24 hours with rock pressure of about 20 pounds per square inch. Gas burns with bluish flame and gives off sulphur. From the well that was drilled 300 feet to the east I obtained several gallons of drillings that were washed in from the new well. This indicates that the flow of the water is to the east and opposite to the dip of the rocks
	44	184-189	Gray, slightly phosphatic, sandy pyritiferous limestone	
	45	189-191	Slightly phosphatic, gray, sandy, pyritiferous limestone	
	46	191-193	Slightly phosphatic, gray, sandy limestone	
	47	193-198	Gray, slightly phosphatic limestone	
	48	198-205	Gray, slightly phosphatic limestone	

Age and formation	Sample No.	Depth (in feet) at which sample was obtained	Author's description of samples	Description of rocks and remarks by engineer in charge
ORDOVICIAN, Hermitage formation	49	205-205.7	Gray, calcareous shale	Soft, bluish-gray, shaly limestone[b]
	50	205.7-208.3	Gray, fossiliferous, fine-grained, slightly phosphatic limestone and gray shale	Hard, bluish-gray limestone
	51	208.3-210	Gray, sandy, pyritiferous, slightly phosphatic limestone	Hard, bluish-gray crystalline limestone
	52	210-215	Black, calcareous shale	Hard, bluish-gray, crystalline limestone
	53	215-219	Finely crystalline, dark-gray, slightly phosphatic, argillaceous, fossiliferous limestone	Very hard, bluish-gray limestone
	54	219-224	Same as sample No. 53 except no fossils were seen	
	55	224-228		Very hard, bluish-gray limestone; trace of gas
	56	228-230	Finely crystalline, light-gray and dark-gray, argillaceous, slightly phosphatic limestone	
	57	230-234	Same as sample No. 56 but shows fossils	
	58	234-240	Same as samples Nos. 60 and 64, but shows fossils	
	59	240-242	Fine-grained, slightly phosphatic, argillaceous limestone	
	60	242-248	Same as sample No. 64	Very hard, bluish-gray limestone; trace of gas and black oil
	61	248-250	Calcareous, argillaceous material, probably all shale	
	62	250-255	Calcareous, gray shale	
	63	255-259	No sample	
	64	259-261	Fine-grained, dark-gray, slightly phosphatic limestone and slightly calcareous, gray shale	

[b]Drilling operations from the sulphur water down indicate a series of hard blue limestone beds of fairly uniform thickness separated by several inches of softer material.

ACCUMULATION OF OIL AND GAS

CONDITIONS OF ACCUMULATION

The conditions for the accumulation of oil and gas have been briefly but clearly stated by Dr. A. H. Purdue, the State Geologist, after whom the following is quoted.*

"The general conditions under which oil and gas occur are well known among geologists, and may be stated as follows:

1. There must be a source for the oil and gas.
2. There must be a reservoir to contain them.

"*The source of oil and gas.*—Concerning the origin of oil and gas, there are those who think they are formed by chemical reactions that take place within the earth, between different minerals; and those who think they are formed by reactions that take place as the result of organic matter in the rocks. Most geologists, perhaps all, use the latter as a working basis. That is to say, one of the first things they consider when a prospective new field is brought to their attention is whether or not any of the rocks beneath the surface ever contained a good supply of organic matter. If so, this fact, in so far as it goes, is encouraging. The organic matter was put down with the rock beds in which it occurs.

"There are those who believe that oil and gas were formed from the remains of animals that lived in the sea at the time the beds were put down; and others who think that they were formed from the remains of plants that grew in the water where the beds were formed, and still others who think the plants were washed in by streams. Plant remains in beds now being formed beneath water have both sources, and doubtless have had ever since there were plants on the earth. The reasonable supposition is that both have contributed to the formation of oil and gas. Likewise, any given reservoir of oil and gas might have had an animal origin or a plant origin, or it might have come partly from the one source and partly from the other.

"*The reservor.*—It is plain that oil and gas can not accumulate, either in large or small amounts unless the rocks are capable of receiving and holding them. To receive them, there must be cavities of some kind. These may be open spaces in coarse-grained rocks, or joints in fine-grained ones. The coarse-grained, porous rocks are usually sandstones or conglomerates, the former being composed of coarse grains of sand, and the latter at least largely, of gravel, cemented together. Rocks of this kind form the best reservoirs. As gas will move more freely than oil, a reservoir for gas may be in finer-grained rock than for oil. In the same way, a reservoir for very thin oil may be in finer-grained rocks than for thick oil. Sandstones and conglomerates are the com-

*Purdue, A. H., Oil and gas conditions in the Central Basin of Tennessee: The Resources of Tenn.; vol. 6, no. 1, pp. 4-8, 1916.

mon porous rocks, and so frequently are they the rocks from which oil and gas are delivered to the surface, that drillers in quest of these products are on the constant lookout for 'oil sands'; but they call any rock that yields oil a 'sand'.

"The fine-grained, or rather the close textured rocks that contain oil and gas, are limestones and shales. Water, like oil and gas, will flow through the coarse-grained sandstones and conglomerates, and many of these are the source of water supply. But if water in quantity is found in close textured limestone or in shale, it must come from joints. The same is true of oil and gas. Such rocks are not considered so desirable as sandstones, for reservoirs.

"Oil and gas nearly always occur in stratified rocks, by which is meant those that are in layers or beds. Igneous rocks are not in well defined layers and but few are known to contain oil and gas. The best conditions in rocks saturated with water, occur where the rock beds are bowed upward, forming anticlines. Where the rocks are dry, the oil tends to move down any possible slope and accumulate in the troughs or synclines. Hence in regions of saturated rocks, the anticlines are sought by experienced oil men, while in regions of dry rocks, synclines are sought. Since it is more common to find the rocks saturated than dry, attention is mainly directed to the anticlines.

"Another essential for a reservoir is that the open rock be covered with a 'tight' or close textured one, so as to seal the oil and gas in. Without such a covering, these elusive products will escape upward and be scattered through the overlying rocks in inappreciable amounts, or what is more probable in the case of gas, will be given off into the air above.

"It seems not improbable that nearly all stratified rocks originally contained organic matter that has produced more or less gas or oil, but if so, most of these have given up their products by dispersion to other rocks and to the atmosphere, from want of adequate sealing-in conditions. In the case of oil under such conditions, much of the gaseous matter has escaped from it, leaving asphalt and its kindred products, such as albertite, ozokerite, grahamite, and gilsonite.

"Yet another condition usually given as an essential for a reservoir, is that the open rock be underlain by a tight layer, like the overlying one, for the reason that oil or gas may be dissipated downward as well as upward.

"*Size of the reservoir.*—The size of the reservoirs in which oil and gas are stored may not be larger than a pea, or it may cover many square miles. Examples of the small ones may be found in many limestones, in which occur cavities filled or partly filled with petroleum. Such limestones are seductive, for they excite prospecting, but seldom yield oil in paying quantity. The cavities may be numerous and all may contain some oil, but they are not connected, and consequently there is no possibility of the oil flowing from one to another and finally into the drill hole, from which it can be pumped to the surface.

"Most of the large reservoirs are in sandstone, the storage space being composed of the infinite number of pores between the sand grains composing the rock. In fact each one of these small pores is a reservoir in itself, but they are all connected, and because of this the oil or gas will flow through the rock a limited distance to a drill hole. The actual distance through which it will flow varies, being short for small pores and low rock pressure, and comparatively great for large pores and high pressure.

"*Shape of the reservoir.*—Where folding is a factor in forming the reservoir, its shape depends upon that of the structural features. If in an anticline, and the anticline be dome shaped the outline of the reservoir will be circular; but if the anticline should be of the common, elongated kind, the reservoir will be more or less linear in outline. For this reason, geologists and experienced well drillers work out the structure and follow it, not only in trying out an undeveloped field, but if the rocks prove to be saturated with water, in extending it after a successful well has been drilled.

"But here the layman must be warned against making the common mistake of supposing that the bending of the rock layers conforms to the surface irregularities. The rock layers can not be supposed to bow upward where there are hills and downward where there are valleys. If they are not level, they perhaps more commonly bow downward in the hills as synclines and upward beneath the valleys as anticlines; or more commonly yet, they dip in one direction as monoclines. In the latter case, the hard rock layers occur in the ridges, and the soft ones in the valleys.

"*Angle of the rock beds.*—Folded rock beds may stand at any angle from near the horizontal to the perpendicular. The most desirable position for oil and gas is the one near the horizontal. This, for the reason that the lower the dip the wider the anticline and consequently the larger the field; and for the further reason that it is easier for the driller to put down a straight hole in rocks of low than of high dip. If the rocks dip as much as 20 degrees, it is difficult to drill a straight hole, especially if they consist of alternating beds of shale and sandstone or other hard rock. When the drill passes through a soft bed and strikes a high-dipping hard one, the tendency is for the bit to slip downward over the hard surface, and turn the hole away from the perpendicular. Yet, with care, an experienced driller can put down a straight hole in alternating beds of sandstone and shale that dip 20 degrees, or even more.

"*Horizontal reservoirs.*—There are reservoirs that consist of lenses of sandstone lying horizontal or nearly so, sealed up in beds of shale. In such cases, neither the geologist nor the driller can locate the reservoir, without drilling. It follows that the striking of such reservoirs with the drill is a matter of chance; and after such a reservoir is struck, its size can be determined only by the driller."

ACCUMULATION IN THE WAYNESBORO QUADRANGLE

As stated above the rocks of the Waynesboro quadrangle consist predominantly of limestone. Not only the limestone but some of the shale and chert are made up in large part of fossils. These fossils are the remains of animals that were buried in the sea while the sediments that later hardened into the rocks of this area were being laid down, and they may have been the source of much oil and gas. In addition the Chattanooga and Ridgetop shales contain carbonaceous matter that may have been a source of these substances. Although these sources may have furnished much oil and gas and although the domes and anticlines that are described above are a favorable type of structure for the accumulation of oil and gas, there appears to be, if we may judge from our present knowledge of the region, no porous reservoir that contains commercial quantities of these substances. There, however, is a possibility that oil and gas may be found in commercial but not relatively large quantities in cracks and crevices.

The rocks of Carboniferous and Cretaceous age are exposed over most of the surface of the quadrangle, and while those of Silurian and Devonian age are exposed over only a small part of the quadrangle they are exposed in most parts of it. Any large quantities of oil and gas that the rocks of Silurian, Devonian, Carboniferous and Cretaceous age may have once contained have therefore reached the surface and there escaped.

In Allen County, Kentucky, adjoining Tennessee, oil is found in porous dolomitic limestones of Silurian and Devonian age, which underlie the Chattanooga shale, the source of the oil. In the Waynesboro quadrangle the Chattanooga shale is usually so thin that it probably could not have been the source of very much oil. On the other hand, the rocks overlying and immediately underlying the Chattanooga are, as stated above, so widely exposed that if they were porous enough to retain oil they would not be likely to retain large quantities of it. The only bed that appears to be sufficiently porous is the Hardin sandstone member at the base of the Chattanooga shale.

Oil and gas if present in large quantities are thus more likely to have been retained in the Ordovician than in the younger rocks. As shown in the generalized section on pp. 208-212 the exposed rocks of

this age are the Fernvale, Arnheim, Leipers, and Hermitage formations, named in order of their age with the youngest first.

The Fernvale formation is composed of shale in its upper part and of hard dense limestone in its lower part, and is exposed in the northwest, northeast, and southeast parts of the quadrangle. It is therefore not likely to contain much oil and gas even in the central, west-central, and southwest parts of the quadrangle where it is not exposed. In some parts of the area it might however be a seal to keep them from excaping upward from formations beneath. The shale in its upper part is thin and probably at no place exceeds 20 feet in thickness. The only known occurrence of the Arnheim limestone in the quadrangle is at an exposure on the right bank of Tennessee River at Clifton. The Leipers limestone contains some shale that might act as a seal for oil and gas but the interbedded limestone layers are not porous and hence could not hold much oil and gas even where the limestone is favorably situated for their accumulation and retention. The limestone is exposed in the southeast part of the quadrangle and would not now yield any oil and gas there if it ever contained them. It may underlie the northeast, central, and southwest parts of the quadrangle but it is absent in the northwest part. The Bigby limestone has been penetrated in the two wells at Iron City as above stated. A flow of gas estimated at 5,000 cubic feet per 24 hours with a rock pressure of 20 pounds per square inch is reported to have been obtained from the base of the Bigby in the last well drilled at that place. The gas may occupy fissures in the limestone but further drilling in the region seems necessary to prove this.

The Hermitage formation being composed of interbedded shale and limestone in about equal proportions, is probably the most impervious cap for oil and gas in the rocks of Ordovician age. If it should at any place be porous enough, it might yield paying quantities of oil and gas in the east half and southwest quarter of the quadrangle, but it could not be expected to yield these substances in those domes in the northwest part of the quadrangle that reveal the Hermitage on their crests. The exposed limestone layers in this formation are fine-grained and are not porous. They thus could not be the reservoir for any considerable quantity of oil and gas. Relatively small quantities of them may however be found in fissures. The flow of gas from the earlier-drilled well at Iron City and the trace of gas and oil from the later-drilled well at that place are from the Hermitage formation.

The Hermitage formation and Bigby limestone are of Trenton age. Rocks of this age are still looked upon with favor by many drillers because they are the rocks that supplied the northeastern Indiana and northwestern Ohio (Lima-Indiana) field which was in prominence 10 to 20 years ago. Such a view regarding the rocks of Trenton age in Tennessee is a mistake because they differ from those in the oil-producing parts of Indiana and Ohio. There the oil-producing limestones have been made porous by the process of the changing of the limestone to dolomite* whereas the limestones of Trenton age in Tennessee have undergone no such change.

Rocks of Ordovician age older than the Hermitage are not exposed in the Waynesboro quadrangle nor have they been penetrated in wells there. Their exact character is not known but they probably comprise the following formations named from the upper to the lower ones: Carters, Lebanon, Ridley, Pierce, and Murfreesboro limestone of Lower Ordovician age and the Knox dolomite, of Lower Ordovician and Upper Cambrian age. The Knox is a massive dense dolomite and is exposed in the Wells Creek basin in the southwestern part of Stewart County and in a large part of the Valley of East Tennessee. It is probably at least several hundred feet thick in the Waynesboro quadrangle and other parts of Central Tennessee. The Ordovician rocks above the Knox outcrop in the Central and Wells Creek basins and aggregate a thickness of approximately 800 feet. Those between the Knox and the Hermitage are close textured and contain no pores in which oil and gas may collect. They however contain joints in which oil may have accumulated.

The Ordovician rocks in the Central Basin have been penetrated in both deep and shallow wells at a number of places. Concerning the presence of oil and gas in them there Dr. A. H. Purdue says:†

> "There are numerous localities over the Central Basin where a small amount of gas and some oil have been sealed in, and these are not infrequently struck in drilling for water. But the oil is insignificant in amount where it occurs at all, and the gas usually exhausts after a

*Orton, Edward, The Trenton limestone as a source of petroleum and natural gas in Ohio and Indiana: U. S. Geol. Survey, Eighth Ann. Rept., pt. 2, pp. 582-587, 1889.

†Purdue, A. H., Oil and gas conditions in the Central Basin of Tennessee: The Resources of Tennessee, vol. 6, p. 12, 1916.

few days' flow. The greatest supply of gas they could be expected to furnish would be for private use, such as heating a residence, or a kitchen range. In most cases, the supply would be too small to justify the necessary piping even for one of these purposes."

CONCLUSION

From the foregoing there appears to be no great possibility of finding oil and gas in paying quantities in the Waynesboro quadrangle unless they be found in fissures in the rocks. If they occur in fissures their yield would probably be relatively small and their occurrence sporadic. The prospecting that is to be carried on should be done on or near the crests of the domes and anticlines described above. The possibility of finding oil and gas in the rocks above the Knox dolomite is probably greater than in the Knox. Therefore no well should be drilled which would penetrate more than 800 feet of Ordovician rocks. This amount, as stated above, is the estimated thickness of the Ordovician rocks overlying the Knox dolomite in Middle Tennessee.

General Oil and Gas Conditions of the Highland Rim Area in Tennessee

By A. H. Purdue

INTRODUCTION

It should be stated at the beginning of this paper that a careful investigation of the oil and gas conditions over the Highland Rim of Tennessee has not been practicable except for that part covered by the Waynesboro quadrangle, the results of which are contained in the preceding paper by Mr. Miser. The justification of the statements herein, though only of a general nature, is in the large number of inquiries that come to this Survey about the oil and gas possibilities in the State, and also in the desirability of public knowledge of all those areas where the conditions indicate a possibility of oil, even though they may not be very encouraging.

LOCATION OF THE HIGHLAND RIM

The name, Highland Rim, seems first to have been applied to that surface division of Tennessee herein considered, by the late Dr. James M. Safford.* It completely surrounds another important surface feature of the State, which Dr. Safford called the Central Basin†.

That part of the Highland Rim on the east of the Central Basin lies between the latter and the western escarpment of the Cumberland Plateau, which in places rises above the Rim upwards of 1000 feet, and which is indented by many stream valleys, large and small. On the north, the Highland Rim passes into the rather level region of middle Kentucky, and on the west it comprises the highlands between the Central Basin and Tennessee River, which in southern Tennessee and northern Alabama, merge into those of the eastern Rim.

*Geol. of Tenn., p. 81, 1869.
†Ibid., p. 97.

The eastern Rim includes parts of the counties of Franklin, Coffee, Grundy, Warren, Cannon, Van Buren, DeKalb, White, Putnam, Overton, and Pickett; the northern Rim, the northern parts of Clay, Macon, and Sumner counties, and all of Robertson County; the western Rim, Montgomery, Stewart, Houston, Humphreys, Dickson, Cheatham, Hickman, Perry, Lewis, Wayne, and Lawrence counties, a little of the western part of Maury County, of the western part of Williamson County, and the northwestern part of Davidson County. A small part of the southern parts of Lincoln and Giles counties constitute that part of the southern Rim in Tennessee.

The geological map of Tennessee, recently issued by the State Geological Survey, distinctly shows the area of the Central Basin (in red) and that of Highland Rim (in purple and gray).

SURFACE

The Highland Rim stands from 300 to 500 feet above the Central Basin, a like distance above the general surface of West Tennessee, and from 800 to 1050 feet above sea level. It is therefore a plateau of moderate height, but the surface is generally uneven and in parts rugged, made so from the numerous stream valleys of the area.

ROCKS

The rocks of the western Highland Rim are represented in the Waynesboro quadrangle and have been described by Mr. Miser in the preceding paper (pp. 207-212). Those of the eastern Rim are in general the same as those of the western one, with the exception of the Silurian and Devonian rocks, which are there wanting.* It follows that the Chattanooga shale which is used by Mr. Miser as the datum for determining the structure of the Waynesboro quadrangle, rests, in the eastern Rim, on rocks of Ordovician age, instead of on those of Silurian and Devonian age, as it does in most of the western Rim, and in the western part of the northern Rim.

STRUCTURE

The type of structure in the Waynesboro quadrangle as shown by Mr. Miser's map accompanying the preceding paper, is prevalent

*Whether the Chattanooga shale is of Devonian or Mississippian age is undecided.

over those parts of the Highland Rim that have come to the writer's attention, and it probably is common to all of it, as well as to all of Middle Tennessee, for such detailed geological work as has been done in the Central Basin* shows it to obtain there also.

As is generally known, the structure should have careful attention in all regions that are being prospected for oil, provided the conditions are such that it can be made out. These conditions prevail in the Highland Rim, though they are easier of interpretation in some parts than in others.

The Chattanooga shale is easier to recognize than any of the other formations of the area, because of its black color, its oily nature, its softness, and the (Hardin) sandstone, which in most places underlies it. For this reason, the Chattanooga shale is, where exposed, a convenient reference for locating the anticlines and synclines, which in this area are usually of so uncertain extent that they perhaps more properly could be spoken of as domes and basins.

This shale is exposed all around the inner edge of the Highland Rim, but is not to be seen in many places away from the edge, except in the southern part of the western Rim—the part covered by Perry, Lewis, Hickman, Lawrence and Wayne counties, where it outcrops along the sides of the valleys. With this as a datum, the structure is not difficult to determine, in the counties named. Because this easily recognizable formation is generally under cover of other rocks in other parts of the Highland Rim, the geologist will there have to depend upon the less definite Ridgetop shale and Fort Payne chert, in working out the structure.

The reader of Mr. Miser's paper should carefully note that he says the streams as a rule flow in synclines. This is plainly shown in his map. It follows that most of the anticlines of the area lie between the streams, and that as a rule the most likely places for successful drilling are on the divides and not in the valleys where most of the test wells of the western Rim seem to have been located.† Let

*Hayes, C. W., and Ulrich, E. O., U. S. Geol. Survey, folio No. 95; and Galloway, J. J., and Coryell, C. N., unpublished map and manuscript of Rutherford County.

†For an account of these see Munn, M. J., Tenn. Geol. Surv. Bull. 2-E, pp. 34 and 35, 1911. A well recently drilled three-quarters of a mile south and west of the railroad station at White Bluff has a strong flow of artesian sulphur water. The depth from which this comes was not ascertained. No oil is reported. It was put down in a valley.

it be understood that this statement applies to this region but should not be blindly followed elsewhere, for in many others it does not hold.

The careful reader will at once infer that a locality on the Highland Rim about which streams head, and from which they flow in opposite directions, is one of dome or anticlinal structure. This is a pretty safe inference, but before money is spent in drilling it should be confirmed by a capable geologist, for there probably are such areas in which the rock beds are horizontal, and some of them may even be synclinal. Again, there are parts of valleys in which the structure is anticlinal.

POSSIBLE OIL HORIZONS

A complete account of the wells that were drilled in the Highland Rim up to 1911 has been published by this Survey,* but the well records obtainable were so indefinite that the exact horizons from which oil was secured can not be determined.

The St. Louis limestone produces oil in the Cumberland Plateau† but it could not be expected to do so in the Highland Rim, for the reason that it there is not covered by other rocks. The oil-producing formation in the Spring Creek district of Overton County is thought by Munn to be the Fort Payne formation‡, but most of the oil of the Highland Rim has come from various depths below the Chattanooga shale, which underlies the Fort Payne.

The Chattanooga shale contains enough oil to make it burn easily, and it seems probable that downward moving water has carried oil from this formation into the joints of the limestone beneath, and into sand beds should such anywhere occur, though with the exception of the Hardin sandstone, just beneath the shale, none are known; and the Hardin sandstone is not everywhere present. Much of the oil in the Irvine field, Estill County, Kentucky, is secured just beneath this shale. That from the Scottsville field, Allen County, Kentucky, is reported to be secured at varying depths from a few feet to 100 feet or possibly even more, beneath the shale.

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*Munn, M. J., Preliminary report upon the oil and gas developments in Tenn., Bull. 2-E, 1911.

†Glenn, L. C., Tenn. Geol. Surv., Res. of Tenn., vol. VII, no. 1, p. 42.

‡*Ibid*,, p. 8.

Even if the surmise is true that the oil within a reasonable distance beneath Chattanooga shale has been derived from it, the chances for successful wells from this horizon in the southern part of the western Highland Rim are not considered great, for the reason that the shale there is as a rule not thick and in places is absent. (See page 201). But the evidence is that this shale thickens to the north and this fact stimulates the hope for oil beneath it in the northern counties of the Highland Rim, in the anticlines or domes of that area. The Scottsville oil field which is just across the State line in Kentucky gives encouragement, for the sequence of the rocks and other conditions there are presumably the same in adjoining parts of Tennessee.

Oil has been found on the Highland Rim in Overton and Pickett counties* both above and some distance below the Chattanooga shale.

The record of a "dry hole" at McMinnville, Warren County, shows the Chattanooga shale to be 55 feet thick. This thickness of the shale and the necessary structural conditions, would be good ground for hope of striking fissure oil at some point not far below the shale, on the eastern Highland Rim; but it appears that this thickness of the shale can not be relied upon in that area, for it is reported only 10 to 12 feet thick, one mile northwest of Tullahoma.†

Below the rocks underlying the Chattanooga shale, the best hope for oil is in or beneath the Hermitage limestone, described by Miser (p. 202), for the reason that the shale of that limestone may serve as a cover for an oil reservoir, or may even be a source of oil. The depth of this limestone below the Chattanooga shale varies with the locality. In the Columbia quadrangle, which covers a part of Maury and adjacent counties, the top of this limestone is from 70 to 400 feet below the Chattanooga shale, and the Hermitage itself is from 40 to 70 feet thick.‡

According to the foregoing tables by Miser, the distance from the Chattanooga to the Hermitage in the Waynesboro quadrangle varies from 21 to 570 feet, and the Hermitage there exceeds 80 feet in thickness. In Rutherford County, according to Dr. J. J. Galloway, the distance from the Chattanooga shale to the top of the Hermitage

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*Munn, M. J., Tenn. Geol. Surv., Bull. 2-E.

†Munn, M. J., Tenn. Geol. Surv., Bull. 2-E, p. 26.

‡Hayes and Ulrich, *Loc. cit.*

varies from 200 to 430 feet,* and the Hermitage itself is from 70 to 80 feet.

Records for the northern part of the Highland Rim are not available, but the distance from the Chattanooga shale to the Hermitage limestone probably increases northward, for the reason that the Devonian rocks become thicker westward and northward from the Waynesboro quadrangle. Data are not at hand from which the amount of this thickness can be estimated. From Stewart County eastward, the Silurian rocks and those of Devonian age beneath the Chattanooga shale thin, and from investigations to the present, do not occur east of Macon County.

The Camden chert, which is of Devonian age, is well exposed in the eastern parts of Benton and Henry counties. In much of this area, erosion has removed the overlying Chattanooga shale and higher rocks, and in such parts there is no hope of oil from the chert, though it may there occur at some of the horizons beneath, later to be mentioned. This chert thins out eastward, somewhere beneath the western Highland Rim, but its presence within 10 miles east of Tennessee River opposite the counties named, can pretty safely be relied upon. In this area, the Chattanooga shale probably is present, underlying the Ridgetop shale. If suitable structure can be found, it will be worth drilling, for the chert probably is much jointed, and if so, supplies one of the necessary conditions for oil accumulation.

The lowest formation described in Mr. Miser's table is the Hermitage limestone (p. 202). Below this, in descending order, the following rocks are exposed in the Central Basin:

MIDDLE ORDOVICIAN

Carters limestone. 40 to 85 feet. "Heavy-bedded, fine-grained, white or light-colored limestone, often containing chert and silicified fossils."†

LOWER ORDOVICIAN

Lebanon limestone. 70 to 120 feet. The following is the description of this limestone in Rutherford County: "Thin-bedded, dense, brittle, dove, blue or brown limestone with shaly partings; beds 1 to 6 inches thick; massive bed of drab limestone 10 or more feet thick near middle; fossils frequently abundant."‡

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*Unpublished manuscript.

†Hayes and Ulrich, U. S. Geol. Surv. folio 95.

‡Galloway, J. J., unpublished manuscript.

Ridley limestone. 100 feet. "Dense, drab, brittle, massive limestone, weathering gray and granular, fluted or platy; sometimes very cherty; oily smell on breaking.*

Pierce limestone. 23 to 28 feet. "Platy layers of dense, blue or drab, brittle limestone, very fossiliferous (Bryozoa) with shaly partings; heavy beds of bluish-brown coarse, crystalline limestone frequently present.*

Murfreesboro limestone. 70+ feet. "Dense, drab, brittle, massive limestone, oily smell on breaking, much black chert on weathering, fucoidal markings common; other fossils rare except in chert.* Total thickness, 130 to 398 feet.

These formations extend from the Central Basin in all directions under the Hermitage limestone, consequently beneath the Highland Rim.

There is hope that the shale of the Hermitage limestone is sufficiently intact to confine such oil as may possibly have accumulated in the joints of the underlying Carters limestone. Besides, it is possible that the shale of the Hermitage is a source of oil.

It will be noticed that Dr. Galloway describes the Ridley and Murfreesboro limestones as having an oily smell, when broken; and it may be that when these are under the cover of the rocks of the Highland Rim they would produce some oil from fissures. While these limestones are not urged as possible oil reservoirs, they are the more hopeful because of the overlying, compact, rather shaly Lebanon limestone.

DEPTH TO DRILL

The distance to the Chattanooga shale will depend mainly on the altitude of the mouth of the well. As above stated, the divides between the streams are as a rule the best locations for wells because these generally are areas of anticlines. Reference to Mr. Miser's table (p. 201) will show that on the divides the distance to the Chattanooga shale varies from approximately 150 to 500 feet in the Waynesboro quadrangle. One hope for oil in the Highland Rim is in the 50 feet below this shale.

A well once started, should continue to the depth of at least 50 feet below the Hermitage limestone, with the hope of striking oil in a fissure of the underlying Carters limestone, unless it is sooner secured.

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*Ibid.

The Knox dolomite underlies the Murfreesboro limestone. Its thickness in Middle Tennessee is not known, but in East Tennessee it is from 3000 to 4000 feet. It probably is much less in Middle Tennessee. In no case would the writer advise going far into this formation.

MARKERS FOR THE DRILLER

The thickness of the several formations beneath the surface of the Highland Rim, as given in the preceding tables (pp. 208-212) will aid the driller somewhat, but this is unsatisfactory because it is so variable.

The Chattanooga shale will always be recognized from its black color and its softness.

The alternating thin layers of limestone and shale that constitute the Hermitage should make that formation recognizable.

Probably the thin-bedded, blue, somewhat shaly Lebanon limestone could be recognized.

There should be no difficulty in recognizing the Pierce limestone with its brittle, platy layers of lime and its shaly partings, so different from the Ridley above and the Murfreesboro below, provided these characteristics hold beneath the Highland Rim.

Unfortunately, the thickness of the Murfreesboro limestone is not known, for its base is not exposed, and reliable well records are not available. It may be that the driller could notice no change in passing from this into the Knox dolomite.

CONCLUSIONS

The foregoing brings one to the following conclusions regarding oil possibilities in the Highland Rim, where the structure is favorable:

1. There is a small chance for oil in the Ridgetop shale, which overlies the Chattanooga shale.
2. A hope for oil is in the 50 feet below the Chattanooga shale and some distance away from its outcrops on hillsides, in the northern and eastern parts of the Highland Rim. The shale is so thin in the southwestern part that the chances there are reduced.

3. There is a possibility of oil in, or a short distance below the Hermitage limestone, away from the outcrops of that formation.
4. There is some hope for oil in the Ridley and Murfreesboro limestone, beneath the Highland Rim.
5. Oil, if struck anywhere in the Highland Rim, is almost sure to come from fissures, for with the exception of the Hardin sandstone, the rocks so far as known are compact to shaly limestones.

Publications of Geological Survey of Tennessee Issued.

The following publications have been issued by the present Survey, and will be sent on request *when accompanied by the necessary postage.*

BULLETIN No. 1—Geological Work in Tennessee.

A. The establishment, purpose, object and methods of the State Geological Survey; by Geo. H. Ashley, 33 pages, issued July, 1910, postage, 2 cents.

B. Bibliography of Tennessee Geology and Related Subjects; by Elizabeth Cockrill, 119 pages; postage, 3 cents.

BULLETIN No. 2—Preliminary Papers on the Mineral Resources of Tennessee, by Geo. H. Ashley and others.

A. Outline Introduction to the Mineral Resources of Tennessee, by Geo. H. Ashley, issued September 10, 1910; 65 pages; postage, 2 cents.

D. The Marbles of East Tennessee, by C. H. Gordon; issued May, 1911; 33 pages; postage, 2 cents.

E. Oil Development in Tennessee, by M. J. Munn; issued January, 1911; 46 pages; postage, 2 cents.

G. The Zinc Deposits of Tennessee, by S. W. Osgood; issued October, 1910; 16 pages; postage, 1 cent.

BULLETIN No. 3—Drainage Reclamation in Tennessee; 74 pages; issued July, 1910; postage, 3 cents.

A. Drainage Problems in Tennessee, by Geo. H. Ashley; pages 1-15; postage, 1 cent.

B. Drainage of Rivers in Gibson County, Tennessee, by A. E. Morgan and S. H. McCrory; pages 17-43; postage, 1 cent.

C. The Drainage Law of Tennessee; pages 45-74; postage, 1 cent.

BULLETIN No. 4—Administrative Report of the State Geologist, 1910; issued March, 1911; postage, 2 cents.

BULLETIN No. 5—Clays of West Tennessee, by Wilbur A. Nelson; issued April, 1911; postage, 4 cents.

BULLETIN No. 9—Economic Geology of the Dayton-Pikeville Region, by W. C. Phalen; issued May, 1911; postage, 4 cents.

BULLETIN No. 10—Studies of the Forests of Tennessee.

A. An Investigation of the Forest Conditions in Tennessee, by R. Clifford Hall; issued April, 1911; 56 pages; postage 3 cents.

B. Chestnut in Tennessee, by W. W. Ashe, issued December, 1911; postage, 2 cents.

C. Yellow Poplar in Tennessee, by W. W. Ashe, issued January, 1914; 55 pages; postage, 3 cents.

BULLETIN No. 13—A Brief Summary of the Resources of Tennessee, by Geo. H. Ashley; issued May, 1911; 40 pages; postage, 2 cents.

BULLETIN No. 14—The Zinc Deposits of Notheastern Tennessee, by A. H. Purdue; issued September, 1912; 69 pages; 30 illustrations; postage, 3 cents a number.

BULLETIN No. 15—Administrative Report of State Geologist, 1912.

BULLETIN No. 16—The Red Iron Ores of East Tennessee, E. F. Burchard; issued November, 1913; 172 pages; postage, 8 cents.

BULLETIN No. 17—The Water Powers of Tennessee, by J. A. Switzer; issued April, 1914; 137 pages; postage, 8 cents.

BULLETIN No. 18—Administrative Report of the State Geologist, 1914.

BULLETIN No. 19—Elevation in Tennessee, by Elizabeth Cockrill; issued 1917, 80 pages; postage, 3 cents.

MAPS—Map of Lewis County, 1915; postage, 2 cents.
Geological Map of Tennessee, 1915; postage, 15 cents.
Map of Rutherford County, 1916; postage, 2 cents.
Map of McNairy County, 1916; postage, 2 cents.

"THE RESOURCES OF TENNESSEE"—This is a quarterly magazine, devoted to the description, conservation and development of the State's resources. Postage, 2 cents a number. The following are the volumes and numbers issued, with the title of the principal papers in each number:

Vol. I. No. 1—The utilization of the small water powers in Tennessee, by J. A. Switzer and Geo. H. Ashley. (Out of print).

No. 2—The Camden chert—an ideal road material, by Geo. H. Ashley.
The Fernvale iron ore deposit of Davidson County, by Wilbud A. Nelson.
Cement materials in Tennessee, by C. H. Gordon.
(Out of print).

No. 3—The gold field of Coker Creek, by Geo. H. Ashley.

No. 4—Coal resources of Dayton-Pikeville area, by W. C. Phalen.

No. 5—Economic aspects of the smoke nuisance, by J. A. Switzer.
Watauga Power Company's hydro-electric development, by Francis R. Weller.
The coal fields of Tennessee, by Geo. H. Ashley.

No. 6—Bauxite Mining in Tennessee, by Geo. H. Ashley.
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Dust Explosions in Mines, by Geo. H. Ashley.
The Rejuvination of Wornout Soil Without Artificial Fertilizers, by Geo. H. Ashley.
Tennessee to Have Another Great Water Power, by George Byrne.
Manufacture of Sulphuric Acid in Tennessee in 1911, by Wilbur A. Nelson.

No. 2—The Ocoee River Power Development, by J. A. Switzer.
Exploration for Natural Gas and Oil at Memphis, Tenn., by M. J. Munn.

No. 3—The Power Development at Hale's Bar, by J. A. Switzer.
Notes on Lead in Tennessee, by Wilbur A. Nelson.

No. 4—The Tennessee Academy of Science.
The Preliminary Consideration of Water Power Projects, by J. A. Switzer.
Lignite and Lignitic Clay in West Tennessee, by Wilbur A. Nelson.

No. 5—The Growth of Our Knowledge of Tennessee Geology, by L. C. Glenn.

No. 6—On the Impounding of Waters to Prevent Floods, by A. H. Purdue.
Drainage Problems of Wolf, Hatchie, and South Fork of Forked Deer Rivers, in West Tennessee, by L. L. Hidinger and Arthur E. Morgan.
The Waste from Hillside Wash, by A. H. Purdue.

No. 7—Where May Oil and Gas Be Found in Tennessee? By Geo. H. Ashley.
Spring Creek Oil Field, by M. J. Munn.

No. 8—The Monteagle Wonder Cave, by Wilbur A. Nelson.
Cave Marble (Cave Onyx) in Tennessee, by C. H. Gordon.

No. 9—The Valley and Mountain Iron Ores of East Tennessee, by Royal P. Jarvis.

No. 10—The Iron Industry of Lawrence and Wayne counties, by A. H. Purdue.
Some Building Sands of Tennessee, by Wilbur A. Nelson.

No. 11—Tests on the Clays of Henry County, by F. A. Kirkpatrick. Introduction by Wilbur A. Nelson.
Barite Deposits in the Sweetwater District, by Herbert B. Heneger.

No. 12—The Soils and Agricultural Resources of Robertson County, by Reese F. Rogers.
The Iron Ore Deposits in the Tuckahoe District, by C. H. Gordon and R. P. Jarvis.

Vol. III. No. 1—The General Features of the Tennessee Coal Field North of the Tennessee Central Railroad, by L. C. Glenn.
The Tennessee Coal Field South of the Tennessee Central Railroad, by Wilbur A. Nelson. (Out of print).

No. 2—State Supervision of Forestry, by L. C. Glenn.
Conservation of the Water Powers of Tennessee, by J. A. Switzer.
Water Supplies for Cities and Towns, by A. H. Purdue.
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No. 3—The Gullied Lands of West Tennessee, by A. H. Purdue.
White Rock Phosphate of Decatur County, Tennessee, by T. Poole Maynard.
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Relations of Water Supply to Health, by J. A. Switzer.

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Report on the Water Powers of Tennessee.

No. 4—The Need of a Soil Survey of Tennessee, by C. A. Mooers.
The Geology of Perry County and Vicinity, by Bruce Wade.
Indexes to Volumes III and IV.

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VOLUME VIII NUMBER 1

THE RESOURCES OF TENNESSEE

A MAGAZINE DEVOTED TO THE DESCRIPTION, CONSERVATION AND DEVELOPMENT OF THE RESOURCES OF TENNESSEE

PUBLISHED
JANUARY, APRIL, JULY AND OCTOBER
BY THE
STATE GEOLOGICAL SURVEY
NASHVILLE, TENN.

JANUARY, 1918

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State Geological Commission

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Forester

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Traverseman

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In addition to his duties as a professor in the University of Arkansas, he found a steadily increasing amount of committee and other responsible executive work falling upon his shoulders, and about the time of his leaving there was prominently spoken of in

connection with the presidency of that institution. He preferred, however, to continue his scientific investigations and the outlook for this work in Arkansas not being then particularly bright, because of disturbed political conditions that had cut off the support of the State Survey, he was induced to come to Tennessee, where he succeeded Dr. G. H. Ashley as State Geologist in March, 1912.

His interests were always broader than his immediate specific work and his participation in general community activities was one of his marked characteristics. In Fayetteville, Arkansas, he was a member of the Board of Education and was very actively interested in its work. He made numerous addresses before schools and educational gatherings over the State and represented the faculty of the University on various public occasions.

On coming to Nashville, he soon identified himself with the public-spirited activities of the community and State, and on his death was a member of the Commercial, Rotary and Freolac clubs, of the Tennessee Historical Society, the Engineering Association of Nashville, the State Highway Commission, and had recently been elected president of the Tennessee Academy of Science. He was a delegate from the State to meetings of the Southern Commercial Congress, the Rivers and Harbors Congress, the Exhibition of Chemical Industries, and to good roads and forestry and numerous other such meetings. These serve to give some indication of the breadth of his interests in organizations for general public welfare.

Among more technical scientific organizations, he was a member of the American Institute of Mining Engineers, of the Indiana and the Tennessee Academies of Science, the National Geographic Society, the Association of State Geologists, and the Geological Society of London. In addition, he was a fellow of the American Association for the Advancement of Science, and of the Geological Society of America.

Upon assuming his duties here in March, 1912, Dr. Purdue found the work of the Survey well organized and continued the various lines of investigation that had been initiated by his predecessor. During his administration, however, there has been a great development of the resources of the State, and in furthering this growth it has been necessary from time to time to add new departments to the Survey. A permanent chemist, for example, has been employed and a division of Forestry established and placed in charge of a forester.

Recently, the work of the Survey has been planned to meet any possible demands that might be made because of the war.

Brief reports of work accomplished by the Survey during Dr. Purdue's administration have appeared regularly in the *Resources* and longer ones have been published from time to time as bulletins, while the manuscript reports for still other bulletins are some on hand ready for publication and others in an advanced stage of preparation. Dr. Purdue planned and directed these activities, attended to a large volume of office work, gave freely of his time and energy to general public service, and in addition found time for numerous field investigations, the results of a number of which have appeared in the *Resources.* In this issue appears an article on manganese—a subject made important by our war needs—that was dictated by him in the hospital, while awaiting the hour for the operation. While thus waiting, he also discussed plans for carrying forward the work of the Survey in case he should not recover and continue as its director. He was thus actively at work up to the very last.

Dr. Purdue was especially fortunate in his training, both as a young field geologist in Arkansas and as a student in Stanford University, in having the guidance of Dr. J. C. Branner. His interests and acquirements in geology covered a wide range through his experience as a university professor, an original investigator and State Geologist in Arkansas and Tennessee. He was especially familiar with the stratigraphy and structure of the Paleozoic area of Arkansas and with the natural gas, coal, zinc, slate and underground water resources of that State, as well as the detailed areal geology of quite a number of quadrangles there, which he mapped for the U. S. Geological Survey. In Tennessee, he soon became familiar with the general geology and economic resources of the State, and in planning the work of the Survey kept in mind the practical needs of the State and shaped the activities of the Survey to these ends. His own especial field or subject was the geology of lead and zinc. His publications are quite numerous, cover a wide range of subjects and have appeared as special reports published by the Arkansas, the Tennessee or the U. S. Geological Surveys, or have been contributed to the various scientific journals of the country.

As a man he thought things out carefully and in his viewpoint was sane, level-headed and practical. He would take counsel with others and yet his decisions were his own, and in carrying them out there

was a quiet forcefulness that indicated the strength of the man. He was pleasant in manner, but of quiet and dignified bearing,—well-poised, frank and direct. His friendships were many and unusually firm and lasting.

His death at the early age of fifty-six would seem untimely, and yet he had led a busy life and accomplished much, and the summons from labor unto rest was so brief that any of us might envy him. These thoughts, however, do not lessen the great loss thus suffered by his friends, by the science of geology, or by the State that he had served so well.

The Climate of Tennessee

By Roscoe Nunn, Meteorologist, U. S. Weather Bureau.

INTRODUCTION.

Climatic records were made in Tennessee as far back as the year 1834. Prior to 1870, however, the observations were few and the records fragmentary, and not until about 1883 was there anything like a comprehensive method of studying the climate of the State. In 1883, under the supervision of the United States Signal Service, a State Weather Service was established, with a number of well distributed observation stations, and the publication of a monthly summary of the records thus obtained was begun.

In July, 1891, the meteorological work of the Signal Service was transferred to the Weather Bureau of the U. S. Department of Agriculture, and under the Weather Bureau the importance of the climatological service was more fully recognized. Improvements were made, (1) by more careful supervision of the observations; (2) increasing the number of stations; (3) furnishing better equipment, and (4) systematizing the observations and the publications of data. From 1895 to the present time the Weather Bureau climatic records throughout the United States have been fairly homogeneous in character; that is, there has been uniformity in respect to instruments used, exposure of instruments, and data obtained and published.

It is therefore possible now to give a more accurate description of the climate of Tennessee than ever before, and it is also possible, on account of the uniform system of making climatic records throughout the country during the last twenty to twenty-five years, to make comparisons of the climatic features of Tennessee with those of other sections of the United States.

The physiography of Tennessee has an appreciable effect in causing local climatic variations, and a description of the natural divisions of the State, accompanied by a physiographic map, is therefore given. It also seems appropriate to mention briefly the soils and crops of the State. The principal climatic features are then described and compared with those of some other sections. The local variations of climate in the State are shown by the charts and the tabulated

matter. The tables also contain data for a number of stations outside of the State, for sake of comparison. The charts and tables are fully explained in the text.

In the preparation of this article, the author has made use of the publications of the United States Weather Bureau, particularly of Bulletin Q, "Climatology of the United States", by Alfred J. Henry, Professor of Meteorology, and of "Climatological Data for the United States by Sections", consisting of 106 parts, and issued under the supervision of the Climatological Division of the Weather Bureau. Some special data were kindly furnished by the Chief of the Weather Bureau and the officials in charge of the Weather Bureau stations at Atlanta, Ga., Bismarck, N. D., Columbia, Mo., Dodge City, Kans., Fort Worth, Texas, Indianapolis, Ind., New Orleans, La., and Parkersburg, W. Va.

So complete a climatic survey of the State as is here presented would have been impossible except for the aid given by the faithful volunteer observers in the various parts of the State, some of whom have kept reliable weather records daily for more than 25 years.

These records are on file at the Nashville office of the Weather Bureau.

PHYSIOGRAPHY.

Tennessee lies between parallels 34° 58′ and 36° 39′ north latitude. It is in a latitudinal belt that includes northern New Mexico and a part of California lying just south of the center of the State. It is in the same latitude as central Japan and is not very different in lati-

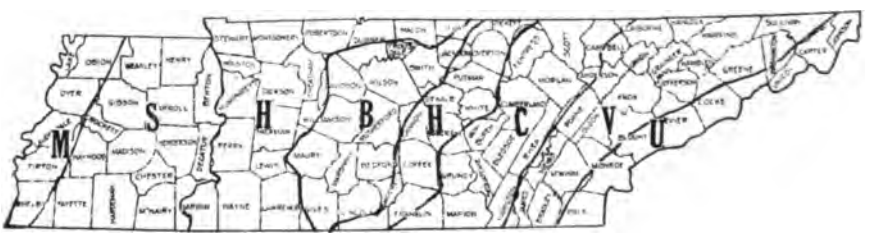

Fig. 1.—Map showing the physiographic divisions of Tennessee.
U.—Unaka Chain, or Smoky Mountains.
V.—Valley of East Tennessee.
C.—Cumberland Plateau.
HH.—Highland Rim.
B.—Central Basin.
S.—Slope of West Tennessee.
M.—Mississippi Bottoms.

tude from the most southern parts of Greece, Italy, and Spain. However, the climates of the foreign districts just mentioned, being modified by their insular positions, are much milder than that of Tennessee. The climate of the California coast is also comparatively equable and mild, on account of the presence of the Pacific ocean to the westward and the prevailing winds that come from the ocean.

Probably there is hardly any other area of equal extent in the United States that presents a more diversified and interesting physiography than Tennessee. In a general way, the surface of the State slopes from the east to the west; from the Smoky Mountains with elevations of 4,000 to 6,000 feet, to the Mississippi bottoms with elevations of 300 to 400 feet above sea-level. This general trend is frequently interrupted, and as a result there are no less than seven natural divisions* of the State, each having its characteristic features. The seven divisions are outlined on the accompanying map, Fig. 1.

The Great Smoky Mountains.—These mountains (in some portions called the Unaka Mountains) mark the dividing line between North Carolina and Tennessee. They are a part of the Appalachian Mountain system. The Smoky Mountain section of Tennessee comprises a belt from two to twenty miles wide along the eastern border of the State. Peaks in this section reach elevations of 4,000 to 6,000 feet, while the general elevation ranges from 2,000 to 3,000 feet, and occasional depressions are as low as 1,000 feet. This is the roughest and most mountainous part of the State. But little of this section is cultivated except the wider valleys or coves, but the lands are used as grazing grounds for cattle in summer. This section has furnished much timber, and parts of the territory are being purchased by the Federal Government for forest reserves.*

The Valley of East Tennessee.—Lying westward from the Smoky Mountain section is the Great Valley of East Tennessee, which is about 30 to 60 miles wide, and runs obliquely across the State from

*The well-known civil divisions of the State—East Tennessee, Middle Tennessee, and West Tennessee—do not follow the lines of natural divisions, except in part. East Tennessee comprises the Smoky Mountain region, the Great Valley of East Tennessee, and the eastern part of the Cumberland Plateau. Middle Tennessee comprises the western part of the Cumberland Plateau, the Highland Rim, and the Central Basin. West Tennessee comprises all the region west of the Tennessee River in its northward course across the State.

*"The Soils of Tennessee", by C. A. Mooers, Vol. V, No. 4 of this magazine.

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In addition to his duties as a professor in the University of Arkansas, he found a steadily increasing amount of committee and other responsible executive work falling upon his shoulders, and about the time of his leaving there was prominently spoken of in

number of days with measurable precipitation is somewhat greater there than here. Compare, for example, the records for Chicago and Nashville. Chicago has on an average 126 days in the year with precipitation; Nashville has 121. At Boston, Mass., the annual precipitation is slightly less than at Nashville, but Boston has 130 days in the year with measurable precipitation to Nashville's 121. These facts are cited to show that the weather is more variable in these northern districts than in Tennessee. This is due to the fact that Tennessee lies outside the most frequented paths of storm movements.

Climate has often been defined as "an average of the general weather conditions". As climatic studies have advanced and more details have been collected, the faultiness of the definition just quoted has been recognized — it is necessary to know a good deal more than the "average" conditions. It is very important to know not only the *averages* of the principal climatic elements,—such as temperature, rainfall, humidity, sunshine, and winds — but also the ranges and extremes of these elements, and their annual and seasonal distribution.

Tables have been prepared, therefore, as far as practicable, to show both the averages and the extremes of temperature and precipitation and also their distribution through the year. The Tennessee stations in the various tables were selected with a view to giving a fair representation to the different sections of the State and exhibiting their respective climatic features. While there are no very great contrasts of local climate in the State, there are some noteworthy differences. The following table shows the stations used, with their locations and altitudes:

CLIMATOLOGICAL STATIONS USED.

Station	County	Division	Elevation above sea-level, feet
Carthage	Smith	Middle	500
Chattanooga	Hamilton	Eastern	693
Clarksville	Montgomery	Middle	550
Decatur	Meigs	Eastern	850
Florence	Rutherford	Middle	560
Greeneville	Greene	Eastern	1581
Jackson	Madison	Western	450
Johnsonville	Humphreys	Middle	364
Knoxville	Knox	Eastern	932
Lynnville	Giles	Middle	770
Memphis	Shelby	Western	274
Mountain City	Johnson	Eastern	2486
Nashville	Davidson	Middle	497
Rugby	Morgan	Eastern	1410
Savannah	Hardin	Western	442
Springdale	Claiborne	Eastern	1058
Trenton	Gibson	Western	345
Tullahoma	Coffee	Middle	1075

One may be familiar with the climate of a place or section in a general way without being familiar with the numerical data, in which case he would gain but little knowledge as to the differences in the climate of, say, his home section, and that of some other section by reading the numerical data for the distant section only. He should have data for both, and then he can make satisfactory comparisons. Data for a number of well known Weather Bureau stations in other states are therefore appended to each table, for convenient comparison.

TEMPERATURE.

The temperature element is usually considered of greatest importance in the climatic data for a place or district. First, the mean temperature is considered by months. The mean for any single month is obtained as follows: Record is made in one column of the highest temperature for each day and in another column of the lowest for each day. At the end of the month averages of the two columns are taken. These averages are the "mean maximum" and the "mean minimum". Then, by taking an average of the mean maximum and mean minimum (adding them together and dividing by 2), the *monthly mean* is obtained.* If a long series of records is used, an average of all the monthly means for any month gives a normal, or general mean for that month, and in publishing climatic data it is customary to say simply "mean" temperature when referring to the general average, or normal. It will be noted that practically all the stations used in the tables have records for twenty years or longer.

Monthly and Annual Mean Temperatures.—The mean temperatures for the State as a whole are as follows; in degrees, Fahrenheit: January, 38.5; February, 40.1; March, 49.1; April 58.5; May, 66.9; June, 74.5; July, 77.2; August, 76.2; September, 70.9; October, 59.0; November, 48.3; December, 40.2; for the year 58.3.

Table 1 gives the mean temperature for individual stations by months and the year. There are decided differences in the means for the various stations. The highest annual mean is 61.4°, at Memphis, and the lowest, 52.3° at Mountain City. The variations in mean temperature over the State are graphically shown in Charts I and II. Chart I shows the mean temperature for the coldest month of the

*It has been found by trial that a mean derived from the two extremes is practically correct, or nearly the same as the mean of hourly readings.

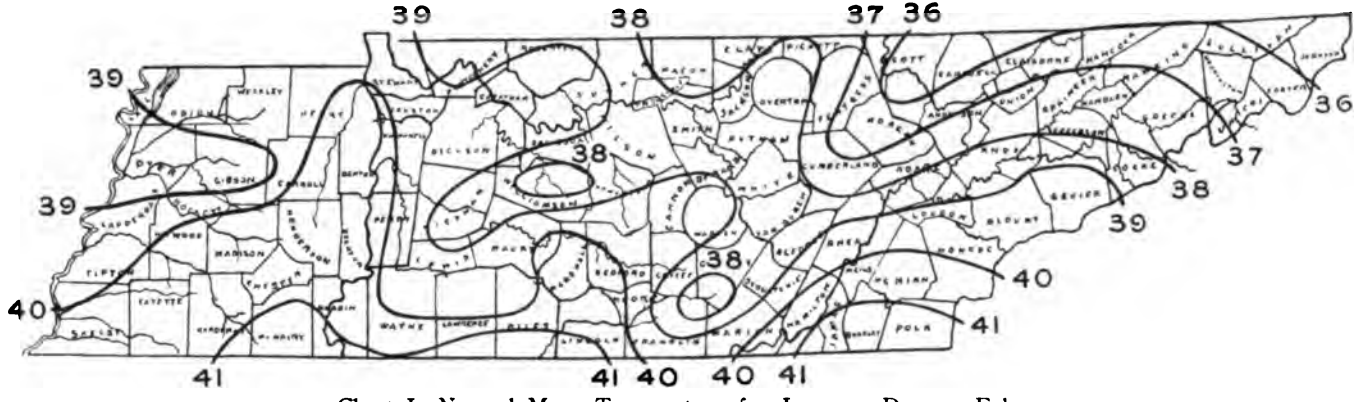

Chart I—Normal Mean Temperature for January—Degrees Fahr.

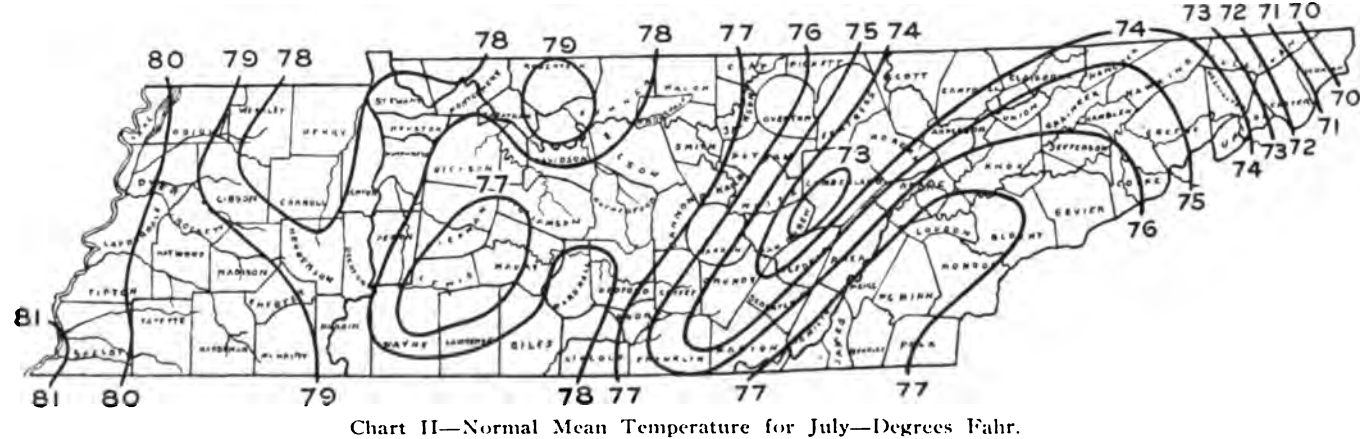

Chart II—Normal Mean Temperature for July—Degrees Fahr.

year, January, and Chart II makes a similar exhibit of the warmest month, July.

The charts show a considerable range of temperature from the southern border to the northeastern border. The decrease in temperature northeastward is due partly to the effects of higher latitude, but mostly to the increased elevation above the level of the sea. Mountain City, the coldest place, has an elevation of 2,486 feet, while Memphis, the warmest place, is 274 feet above sea-level. July is the warmest month in the year on an average. The temperature variations for different parts of the State are decidedly greater in July than in January. It averages 11 degrees warmer at Memphis than at Mountain City in July, but in January only about 5 degrees warmer at Memphis. It is well known that the effect of elevation in reducing temperature is greater in summer than in winter. It is seen from the chart that there is a small area in the extreme northeastern part of the State where the mean temperature for July ranges from 70 to 72 degrees, which corresponds with the mean temperature for the same month at Denver, Col., (72°) Milwaukee, Wis., (70°), Chicago (72°), Detroit (72°), Ithaca, N. Y. (71°), Albany, N. Y. (72°), and Boston (71°). There are large areas in the Cumberland Mountains, not far from the center of the State, where the July mean temperature is between 73 and 74 degrees.

Extremes of monthly mean temperature.—The mean temperature for any particular month may show a wide departure from the normal. It is important to note how much difference there may be, for example, between January of one year and January of another year. For the State as a whole, the coldest January on record was that of 1884, with a mean of 29.4°; while the warmest was that of 1890, with a mean of 50.0°. One January, therefore, may be as much as 20.6° colder than another. In the first case the mean was 9.1° below the normal and in the second 11.5° above the normal, the normal for January being 38.5°.

In July, for the State as a whole, the lowest mean was that of 1891, when it was 74.0°, and the highest was that of 1901, when it was 81.1°; showing that the variations from normal in the warm months are comparatively slight, the normal for July being 77.2°. Similar variations occur, of course, at individual stations.

Absolute extremes of temperature—highest and lowest on record. Table 2 shows the highest temperatures ever recorded for each

month of the year and Table 3 the lowest ever recorded. These data are important, as they indicate the limits of the range that may be expected. Maximum temperatures of 100°, or slightly above, are occasionally reached in all parts of Tennessee except the more elevated portions.

At Nashville temperatures as high as 100° have been registered in only ten summers out of forty-seven. On an average, the temperature reaches 95° or above in the warmer parts of the State on about 10 to 15 days a year, during the period June to September, inclusive. On the Cumberland Plateau and in the Smoky Mountain section the temperature rarely reaches 95°. The low temperature, pure atmosphere, and picturesque scenery of the mountain districts render them very inviting as places of resort in summer. The Highland Rim also enjoys the advantage of its elevation in perceptibly reduced summer temperatures and the freshness of the air, as compared with the places of low elevation.

Comparing extremes of temperature in Tennessee with those of stations in other parts of the United States, we find that Bismarck, N. Dak., has a record of 107°, which exceeds the record of most stations in Tennessee. Indianapolis, Ind., and Omaha, Neb., have records of 106°, which exceed the record at Nashville, while Columbia, Mo., has a record of 111° and Dodge City, Kans., 112°.

Table 3 gives the lowest temperature on record for each month at the various places named. The minus sign (—) is used to indicate temperatures below zero. It is seen that zero temperatures have occurred in Tennessee in each of the winter months. Zero weather, however, is rare for the State generally, but usually occurs at the mountain stations a few times during almost every winter. Records of 5° to 10° above zero, occur pretty generally over the State on about four or five days during the winter, and zero or below on an average of about once in two or three years.

Mean maximum and mean minimum temperatures.—Table 4 shows the average height the temperature reaches at the warmest part of the day, for each month and for the year, and Table 5 shows the average of the lowest point reached during the day. The tables indicate the average extent of the daily range of temperature. For example, the mean maximum for January at Nashville is 47.0° and the mean minimum 31.0°, showing that the daily range, on an average, is about 16° in January. Of course the range is much

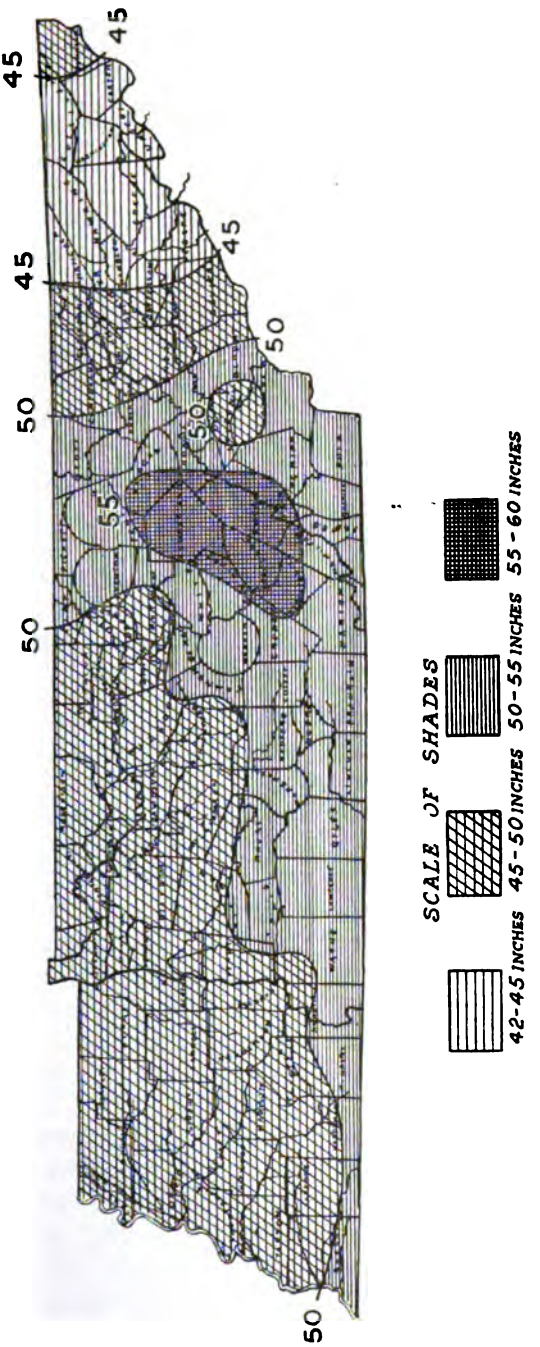

Chart III—Normal Annual Precipitation

greater on some days and much less on others. Cold or warm waves sometimes cause a range of 35 to 40 degrees in one day. Tennessee, however, is comparatively free from great fluctuations, as was stated in "General Remarks".

PRECIPITATION.

Taking the general average for the State, the normal monthly rainfall is as follows, in inches: January, 4.55; February, 4.61; March, 5.21; April, 4.39; May, 4.01; June, 4.26; July, 4.45; August, 3.87; September, 3.08; October, 2.54; November, 3.59; December, 4.49; for the year, 49.05. While the general average for the State is 49.05 inches a year, some localities have considerably more than that and some several inches less. The station with the greatest annual rainfall is Erasmus, Cumberland County, with 59.77 inches; the station with the least annual amount is Bluff City, Sullivan County, with 42.06 inches.

Chart III shows how the annual rainfall is distributed over the State. It is readily seen that the Cumberland Plateau receives the greatest amount, while the least occurs in Sullivan, Greene, and Washington counties in upper East Tennessee. Over the western half of the State the distribution is rather uniform.

Variability of rainfall.—It is observed that the rainfall is rather evenly distributed through the year, on an average. This is shown by the monthly averages above quoted, also by Charts IV, V, and VI, which indicate that the differences in amounts received for the several months are not very great. Chart IV shows the average rainfall for all parts of the State for March, which is the wettest month, and Chart V shows the average for October, which is the driest month. March rainfall averages about double that of October.

Tables 7, 8, 9, and 10, give the total rainfall for each month and year from the beginning of records to the end of the year 1916, for Chattanooga, Knoxville, Memphis, and Nashville. These tables are valuable for their exhibition of all the variations in monthly rainfall that have occurred during a long period of years. These four stations represent well the general conditions in Tennessee with respect to monthly rainfall. It will be readily seen that large variations occur; for example, Chattanooga had as much as 14.74 inches of rainfall in January, 1882, and as little as 1.33 in 1907, while in annual amounts the range is from 67.97 inches, in 1880, to 32.68, in 1904. Somewhat similar extremes are found in the records for Knoxville,

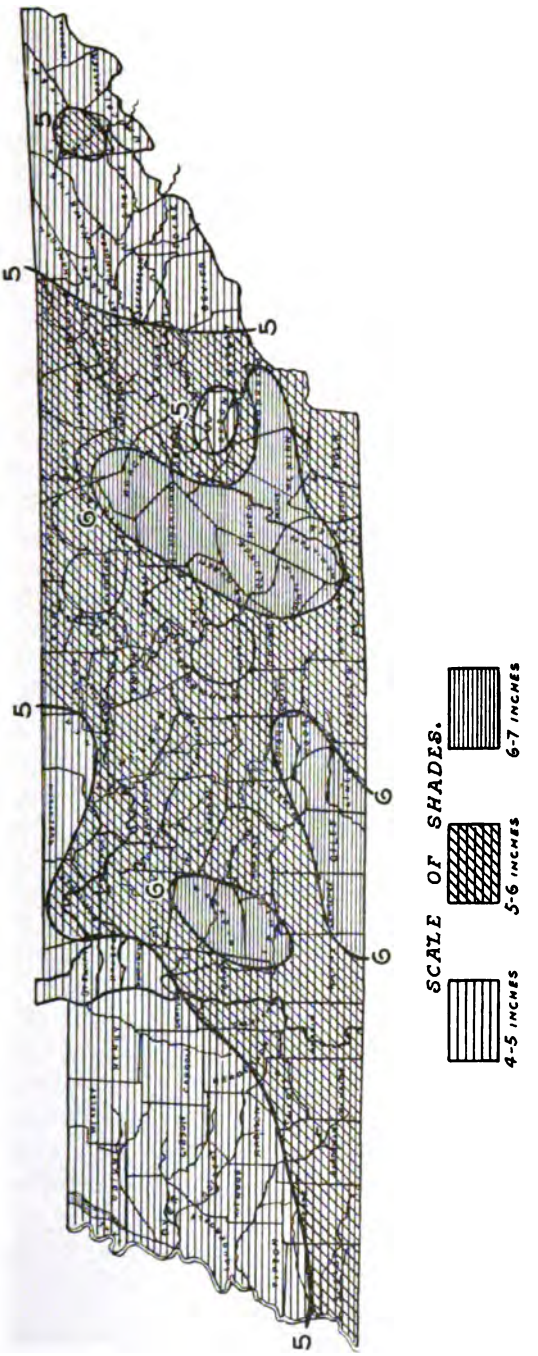

Chart IV—Normal Precipitation for March

Memphis, and Nashville, and also for stations generally in the State.

July rainfall.—Attention is directed to the July rainfall on account of its importance to the corn crop. Copious rains during the period about July 1 to August 10 are essential to the best development of corn in this State. Chart VI shows that on an average the rainfall is ample in July. The normal average for the State is 4.45 inches. In August the rainfall averages about 87 per cent of the July amount, or 3.87 inches.

Frequency of rainfall.—Rain of measurable amount (0.01 inch or more) occurs on an average about 120 days a year in Tennessee. Table 11 shows the average number of days for each month and the year at various stations. The annual number of days varies from 88 to 137. On account of the lack of automatically recording rain gages at the co-operative stations and the absence of strict rule for obtaining the number of days with 0.01 inch or more, the number of days credited with rain at these stations is generally smaller than at regular Weather Bureau stations, where the record for each 24 hours is accurately kept. While the monthly totals at co-operative stations are just as reliable as a rule as those for the regular stations, the strict division of rainy periods into days of 24 hours each (midnight to midnight, as at regular stations) is not possible. If we consider the four regular Weather Bureau stations, Chattanooga, Knoxville, Memphis, and Nashville, we find that Knoxville has the greatest number of days with 0.01 inch or more, viz., 135, while the smallest number, 114, occurs at Memphis.

Rain occurs more frequently in the mountain sections than over the plains of the middle and western parts of the State. The month with the greatest number of days with rain is March, which has 11 days for the State as a whole. The least number occurs in October, which has only 6.

It should be understood that a day with rain does not mean a "rainy" day in the sense that rain falls during most of the day. Many days with 0.01 inch may be clear and fine practically all day. Nor are the days with rain at all regularly distributed through the month but they come most often in periods of 1 to 3 days, with intervals of fair weather lasting from 2 to 10 days. Occasionally rainy spells last 5 to 10 days.

Periods of drought.—By far the greater number of long dry spells occur from the middle of August to the end of November, the period

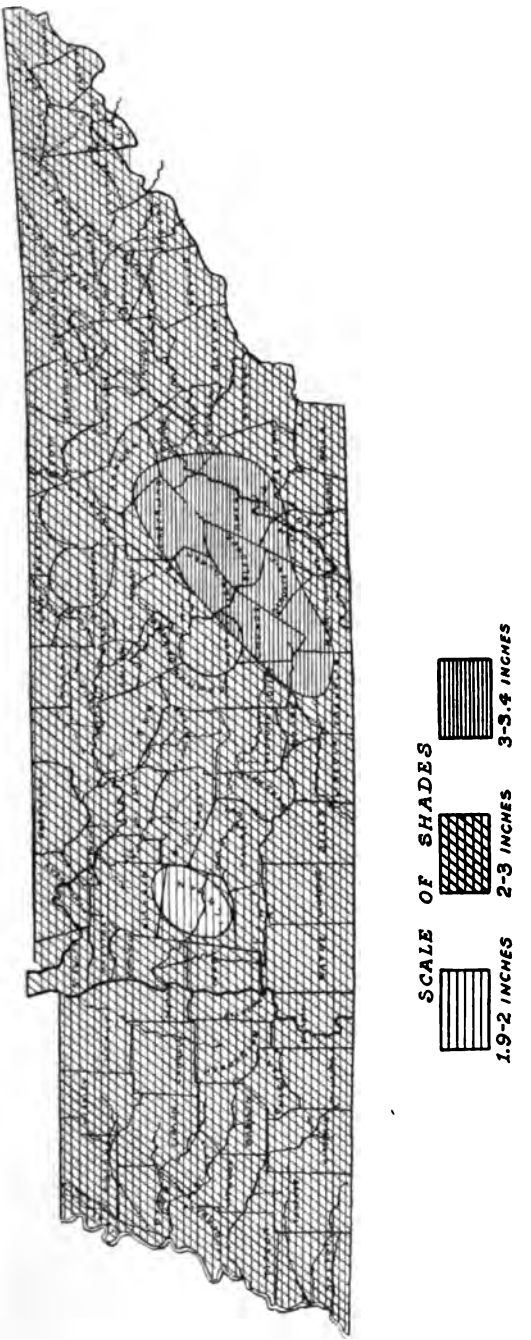

Chart V—Normal Precipitation for October

of maximum occurrence being in October. In a study of this subject from Nashville records we found that in 43 years there were 53 periods of 21 days or longer with less than 0.25 inch of precipitation; but only 10 occurred in the period May 1 to July 31, and in July only 2 in the 43 years.

Special features of precipitation.—Table 12 shows some special features of precipitation. First, it gives the annual number of days that rainfall of given amounts occurs, and shows the relative frequency of these amounts at various stations. Only regular Weather Bureau stations are used, as they are the only stations having the necessary equipment for registering these special features. Secondly, the table shows the relative intensity of rainfall at the stations named. Thirdly, the average date of beginning of the snowfall season in autumn and its ending in spring; also the average annual duration, in days, of measurable snow on the ground.

Snowfall.—The average annual number of days with snowfall of importance—say, one-half inch or more—at Nashville, is 4. The Nashville record no doubt represents the average for the State approximately, but as a rule the snowfall is considerably heavier in the northern tier of counties than in the southern half of the State. The average number of days per season with a fall of 2.0 inches or more at Nashville is 1.4; indicating that, on an average, a snowfall of importance occurs only once or twice a year. In Tennessee a depth of 10 inches or more is seldom seen on the ground, but there have been occasional heavy falls, amounting to as much as 10 to 20 inches, and accumulated depths of 25 inches have occurred.

Tables 12 and 13 give an exhibit of snowfall data for Tennessee and a number of outside points. Taking an average of the records for Chattanooga, Knoxville, Memphis, and Nashville (Table 12), we find that the number of days in a year with the ground covered to a measurable depth (0.1 inch or more) is 6. Chattanooga has an average of 5 days; Knoxville, 7; Memphis, 4; and Nashville, 9. Parts of the mountain sections of course have a great many more days with snow-covered ground than the stations just mentioned.

Special compilations from the records for Nashville show that for the twenty-three years, 1893 to 1916, inclusive, there were four seasons with more than 20 days, all told, when the ground remained covered to a depth of 0.1 inch or more. The greatest total number of such days in any season was 34, in 1894-5. The longest period of

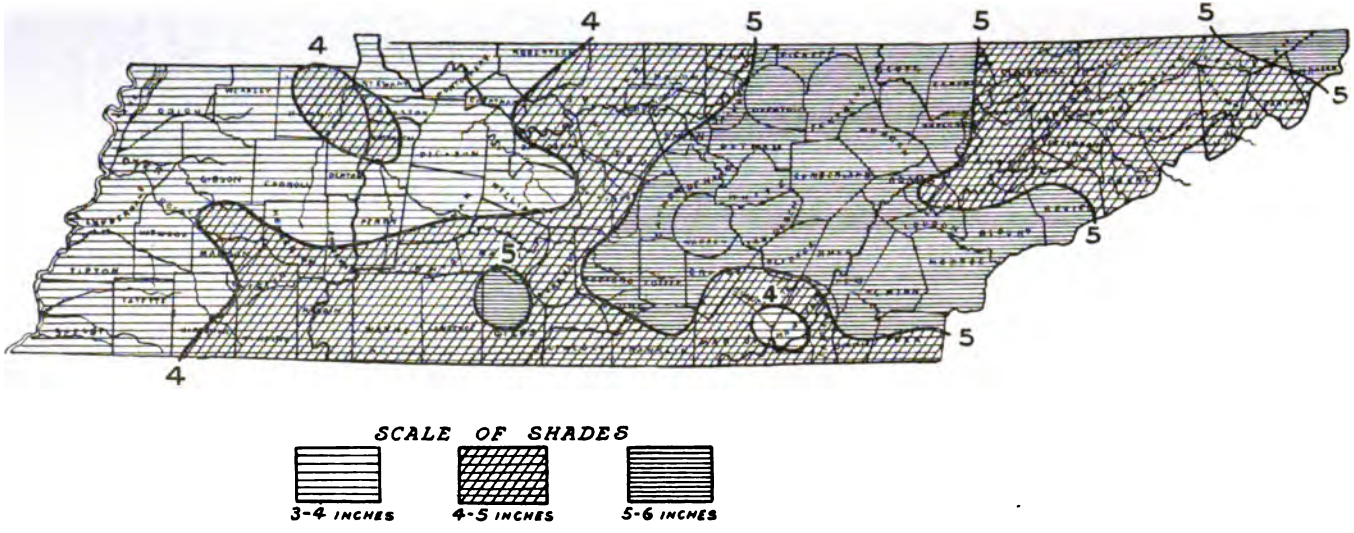

Chart VI—Normal Precipitation for July

consecutive days with snow-covered ground was 21 days, from January 28, to February 17, 1895; the next longest, 19 days, from January 29, to February 16, 1905. There were two winters (1899-1900 and 1907-8) when the ground was not covered at any time with snow.

Humidity.—Table 14 gives the mean relative humidity for each month and the year. These means are obtained from observations made at 7 a.m. and 7 p.m. While the records of humidity are rather incomplete, they are similar in character for all stations, and have value for comparison. By "relative" humidity is meant the percentage of the possible amount of moisture present in the air, or the amount necessary to saturate. If the air be perfectly dry the relative humidity would be 0; if the air be full of moisture, the relative humidity would be 100 per cent. Humidity is an important phase of climate in its relation to bodily comfort and health. The records show that in Tennessee the average relative humidity is moderate, as compared with the general conditions east of the Mississippi River. It is considerably lower than along the Atlantic and Gulf coasts but decidedy higher than in the arid regions of the far southwest.

Sunshine and cloudiness.—Tennessee occupies a medium position in the amount of sunshine received. Table 15 shows the percentage received of the possible amount. The average annual amount for the State is 58 per cent; that is, bright sunshine prevails 58 per cent of the time that the sun is above the horizon. The highest percentage of sunshine occurs in the extreme southwestern part of the United States, where it is at least 70 per cent. The region of least sunshine is in the north Pacific coast States and some distance inland. There are other sections with a very low percentage of sunshine, viz., the lower Lake region, the upper Ohio Valley, and northern New England, where the percentage ranges from 20 to 30 per cent. The average for the United States as a whole is between 50 and 60 per cent.

Frost; length of growing season.—Table 16 gives the average date of the first killing frost in autumn and the last in spring; also the earliest and latest dates on record for a number of stations, and the average length of the crop growing season. For the State as a whole the average date of the first killing frost in autumn is October 22 and of the last in spring, April 9. The average growing season is 196

days. For individual localities there is a considerable range. Frost comes, on an average, about two weeks earlier in the colder parts of the State than in the warmer portions, and in the spring the last frost occurs about four weeks later at the coldest station (Mountain City) than at the warmest (Memphis). The crop growing season, of course, has a similar range.

TABLE I—MEAN TEMPERATURE

Stations	Length of Record, yrs.	Jan.	Feb.	Mch.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	An'l
Carthage	32	38.3	40.2	49.4	58.9	67.4	75.1	77.6	76.8	71.8	59.8	48.6	40.0	58.7
Chattanooga	35	41.8	43.6	51.9	59.6	68.7	75.6	78.4	77.5	72.1	61.3	50.8	42.9	60.4
Clarksville	52	38.0	39.1	48.1	58.0	65.3	74.0	77.6	76.1	70.4	58.1	47.3	39.5	57.7
Decatur	18	40.0	40.0	51.7	58.0	67.9	74.6	77.7	77.3	71.6	59.8	48.3	39.9	58.9
Florence	34	39.0	40.7	49.5	59.0	67.5	75.2	77.5	76.6	71.6	59.7	48.8	40.7	58.8
Greeneville	23	35.4	39.1	47.2	56.1	64.7	72.0	74.6	73.4	69.0	56.9	46.5	39.0	56.2
Jackson	23	40.8	41.3	51.8	60.6	68.9	76.8	79.4	78.8	73.4	60.7	50.7	41.3	60.4
Johnsonville	20	40.0	39.5	51.2	59.2	68.5	75.6	78.9	78.3	72.7	60.4	49.4	39.8	59.5
Knoxville	43	38.5	41.2	49.1	57.9	66.9	74.0	77.0	75.9	70.5	58.8	47.5	39.8	58.1
Lynnville	28	39.3	40.4	49.5	58.2	66.8	74.9	77.4	77.2	71.2	59.6	48.7	41.1	58.7
Memphis	45	40.4	42.5	52.4	61.9	70.4	77.9	80.7	79.4	73.5	62.7	51.6	43.3	61.4
Mountain City	17	35.5	33.7	45.6	50.6	61.3	67.1	70.2	68.9	63.9	53.3	42.4	34.9	52.3
Nashville	45	38.9	40.9	49.5	59.2	68.3	76.1	79.2	78.0	71.9	60.5	48.9	40.9	59.4
Rugby	26	35.0	36.5	46.8	54.5	64.0	71.3	74.1	73.1	67.7	54.9	44.7	37.3	55.1
Savannah	30	41.0	42.2	51.8	60.5	68.8	75.9	79.0	78.3	72.3	60.4	50.2	42.0	60.2
Springdale	20	37.6	39.2	49.1	56.6	65.2	74.0	76.4	76.0	70.0	56.7	45.9	36.8	57.0
Trenton	33	38.6	40.0	49.5	59.6	67.6	75.0	78.0	77.3	71.4	59.3	48.2	39.7	58.7
Tullahoma	27	38.4	39.3	49.3	57.7	66.1	73.1	76.3	75.6	70.3	58.3	47.3	39.9	57.6
In Other States														
Atlanta, Ga.	25	42.9	43.3	53.0	60.4	70.0	76.2	78.1	77.6	73.3	62.4	52.1	43.7	61.1
Bismarck, N. Dak.	42	6.7	9.9	23.5	43.2	54.1	63.6	69.4	67.4	57.6	45.0	27.7	15.2	40.3
Columbia, Mo.	27	30.2	30.3	42.6	54.9	64.5	73.1	76.9	76.0	68.9	57.2	44.2	33.4	54.4
Dodge City, Kans.	31	27.3	31.1	41.7	54.4	63.5	73.1	77.7	76.5	68.2	54.7	40.5	31.6	53.3
Fort Worth, Texas	19	47.0	46.8	57.8	64.1	71.8	80.3	83.1	83.5	77.4	66.7	56.8	46.3	65.2
Indianapolis, Ind.	45	28.7	30.2	40.0	52.5	63.1	72.0	76.1	73.9	67.0	55.3	41.9	32.1	52.8
New Orleans, La.	46	54.3	56.7	62.8	68.8	75.2	80.7	82.3	82.2	79.0	70.5	61.7	55.4	69.1
Parkersburg, W. Va.	29	33.4	32.3	42.8	53.1	63.4	71.4	75.2	73.6	67.8	55.4	44.1	35.1	54.0

TABLE II—Highest Temperature

Stations	Length of Record, yrs.	Jan.	Feb.	Mch.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	An'l
Carthage	32	76	82	90	92	98	104	103	101	102	96	85	74	104
Chattanooga	35	75	78	89	90	95	100	101	101	98	92	81	73	101
Clarksville	26	75	79	87	92	98	107	108	107	105	93	85	73	108
Decatur	18	76	75	91	89	96	100	104	101	100	96	79	72	104
Florence	32	74	75	86	88	94	100	100	100	98	93	79	71	100
Greeneville	23	73	78	82	88	91	95	97	97	96	90	78	69	97
Jackson	13	79	83	82	90	102	104	103	104	103	98	85	72	104
Johnsonville	22	78	80	90	92	100	105	107	103	103	96	88	73	107
Knoxville	43	74	79	87	90	95	99	100	100	99	94	80	75	100
Lynnville	19	73	75	85	91	93	100	102	99	97	94	79	73	102
Memphis	43	79	79	87	90	97	100	104	102	99	92	82	76	104
Mountain City	17	74	71	82	85	89	91	92	93	88	87	78	72	93
Nashville	45	76	77	89	90	96	100	102	104	99	92	81	75	104
Rugby	26	73	76	88	88	95	99	100	98	98	89	80	70	100
Savannah	30	76	77	87	90	96	104	105	104	103	94	84	78	105
Springdale	15	75	77	88	92	95	99	100	100	104	88	79	73	104
Trenton	30	76	80	86	90	100	106	103	100	103	95	85	75	105
Tullahoma	27	74	73	86	90	94	99	100	100	97	91	79	70	100
In Other States														
Atlanta, Ga.	37	75	78	87	89	97	100	100	98	97	94	82	73	100
Bismarck, N. Dak.	42	60	64	81	90	96	103	107	105	102	91	73	64	107
Columbia, Mo.	27	77	81	92	91	96	104	111	105	104	95	84	75	111
Dodge City, Kans.	42	76	83	98	95	101	107	108	105	101	92	85	79	108
Fort Worth, Texas	19	93	96	100	97	103	105	109	112	104	99	87	83	112
Indianapolis, Ind.	45	70	72	84	87	96	100	106	101	98	89	76	68	106
New Orleans, La.	46	82	82	86	90	96	102	102	100	98	94	89	83	102
Parkersburg, W. Va.	29	74	76	86	93	96	99	102	98	99	90	78	72	102

TABLE III—LOWEST TEMPERATURE

Stations	Length of Record, yrs.	Jan.	Feb.	Mch.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	An'l
Carthage	32	—17	—18	— 4	20	33	41	51	47	36	24	10	— 4	—18
Chattanooga	35	— 7	—10	2	25	37	39	56	54	38	27	16	3	—10
Clarksville	26	— 9	—14	4	26	32	43	51	47	35	26	7	— 5	—14
Decatur	18	— 9	—20	2	22	30	40	51	52	34	19	12	1	—20
Florence	32	— 7	—16	3	25	34	42	53	53	35	24	9	— 3	—16
Greeneville	26	—20	—14	3	21	31	35	51	49	28	24	10	— 8	—20
Jackson	18	—10	—13	10	27	31	41	52	49	34	21	8	— 1	—13
Johnsonville	22	—11	—23	4	22	31	41	48	49	30	21	8	— 8	—23
Knoxville	43	—16	—10	5	24	34	42	52	50	35	24	12	— 5	—16
Lynnville	19	— 4	—13	4	25	33	41	53	52	37	24	10	— 2	—13
Memphis	43	— 8	— 9	15	27	40	50	58	58	39	28	16	2	— 9
Mountain City	17	— 8	—16	— 8	15	25	35	40	38	29	14	4	— 9	—16
Nashville	45	—10	—13	3	26	37	42	56	51	38	27	10	— 2	—13
Rugby	26	—17	—19	— 2	16	26	32	42	44	28	16	4	—18	—19
Savannah	30	—12	—10	6	25	32	45	50	51	33	25	10	0	—12
Springdale	16	—15	—24	3	17	29	39	51	51	29	19	7	—11	—24
Trenton	30	—12	—29	8	26	32	42	50	48	30	21	14	— 4	—29
Tullahoma	27	—14	—22	0	22	29	40	41	48	27	22	5	— 5	—22
In Other States														
Atlanta, Ga.	37	— 2	— 8	8	25	38	39	58	55	43	30	16	1	— 8
Bismarck, N. Dak.	42	—45	—43	—36	— 3	13	31	32	32	10	— 2	—28	—42	—45
Columbia, Mo.	27	—20	—26	— 6	18	28	42	45	40	26	19	5	—23	—26
Dodge City, Kans.	42	—20	—26	— 9	13	19	40	46	43	30	10	—13	—15	—26
Fort Worth, Texas	19	1	— 8	22	30	34	48	56	55	40	24	20	9	— 8
Indianapolis, Ind.	45	—25	—18	0	19	31	39	48	44	30	22	— 5	—15	—25
New Orleans, La.	46	15	7	30	38	52	58	66	63	55	40	29	20	7
Parkersburg, W. Va.	29	--12	—27	4	20	31	41	48	45	33	20	15	— 5	—27

TABLE IV—MEAN MAXIMUM TEMPERATURE

Stations	Length of Record. yrs.	Jan.	Feb.	Mch.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	An'l
Carthage	18	50.7	50.2	62.8	71.0	81.2	87.8	90.4	90.2	86.1	75.2	61.9	49.5	71.4
Chattanooga	35	49.7	52.4	61.3	70.1	79.3	85.5	87.7	86.7	82.0	71.8	60.0	51.2	69.8
Clarksville	18	48.1	46.9	60.6	68.2	78.6	86.2	89.3	88.7	83.7	72.1	60.0	47.5	69.2
Decatur	18	50.5	51.1	63.6	71.0	81.6	87.1	89.6	89.5	84.7	74.0	61.3	50.1	71.2
Florence	19	49.1	48.5	60.3	68.0	78.2	84.8	87.1	85.3	82.5	70.1	59.9	48.6	68.5
Greeneville	10	45.6	46.8	60.1	65.9	77.6	83.3	85.9	85.1	81.1	70.9	57.1	42.5	66.9
Jackson	13	50.3	50.8	61.9	70.4	81.4	88.9	91.5	90.5	87.0	74.8	63.0	50.1	71.7
Johnsonville	19	50.8	50.5	63.4	71.7	81.4	88.2	91.3	90.6	86.2	74.6	62.5	49.8	71.8
Knoxville	39	47.2	50.0	59.2	68.4	77.7	84.2	86.9	85.8	81.2	70.2	57.8	47.6	68.1
Lynnville	19	48.8	48.2	60.6	68.0	78.6	85.9	87.8	86.9	82.8	72.0	59.8	48.2	69.0
Memphis	45	48.7	51.3	60.7	70.6	79.0	85.4	89.0	87.9	82.3	71.7	59.9	50.9	69.9
Mountain City	16	45.6	44.2	57.1	63.0	73.8	78.6	80.8	79.5	74.9	65.1	54.1	44.5	63.4
Nashville	42	47.0	49.6	58.7	67.5	78.3	85.6	88.5	87.5	81.9	71.1	58.1	48.8	68.6
Rugby	17	47.0	47.0	60.5	66.4	77.6	83.7	85.9	86.4	82.0	71.1	57.9	46.8	67.8
Savannah	19	51.4	51.8	63.9	71.3	80.8	88.3	90.8	90.8	85.8	74.8	63.0	50.9	72.0
Springdale	14	48.7	49.2	62.9	69.1	81.4	86.5	89.1	88.6	84.1	72.3	59.5	47.6	69.9
Trenton	18	50.3	48.9	62.0	69.2	79.9	87.5	90.2	90.4	86.4	74.8	61.8	48.8	70.8
Tullahoma	18	49.9	49.8	62.6	69.1	78.8	85.3	87.7	87.5	83.4	72.4	60.0	49.0	69.6
In Other States														
Atlanta, Ga.	34	50.2	53.4	62.0	70.0	78.8	84.8	86.8	85.3	81.0	71.0	60.6	52.1	69.7
Bismarck, N. Dak.	42	17.2	20.3	34.0	54.7	66.0	74.9	81.7	80.3	70.6	57.1	38.2	25.1	51.7
Columbia, Mo.	27	39.9	40.1	53.1	66.1	75.6	84.2	87.9	87.8	80.9	69.5	55.2	42.0	65.2
Dodge City, Kans.	36	40.6	44.7	56.4	67.5	75.5	85.0	89.9	88.9	81.6	69.5	54.8	44.9	66.6
Fort Worth, Texas	19	57.6	57.9	69.1	74.6	81.1	90.3	93.1	93.6	87.7	77.6	67.3	55.9	75.5
Indianapolis, Ind.	45	36.0	38.0	48.2	59.8	72.4	81.3	85.5	83.4	76.6	64.5	49.5	38.9	61.2
New Orleans, La.	43	62.0	64.2	70.9	76.4	82.9	87.8	89.1	88.9	85.7	77.7	69.6	62.8	76.5
Parkersburg, W. Va.	29	41.8	40.8	52.0	63.4	74.2	81.8	85.5	84.0	78.7	66.3	53.1	42.9	63.7

TABLE V—MEAN MINIMUM TEMPERATURE

Stations	Length of Record, yrs.	Jan.	Feb.	Mch.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	An'l
Carthage	17	30.5	28.8	39.9	46.3	55.9	63.6	66.6	66.0	60.6	48.6	37.8	30.3	47.9
Chattanooga	35	33.4	34.8	42.5	50.3	58.0	65.8	69.1	68.3	62.7	51.0	41.0	34.6	51.0
Clarksville	18	30.2	28.4	40.4	47.1	57.0	65.0	68.7	67.4	61.5	48.6	38.2	30.6	48.6
Decatur	18	29.6	28.8	39.7	44.8	54.2	62.0	65.8	65.1	58.6	45.6	35.1	29.7	46.6
Florence	19	31.3	30.1	40.9	47.4	57.1	65.1	68.2	67.3	61.4	48.9	38.4	31.6	49.0
Greeneville	10	26.7	26.2	38.5	41.9	52.6	60.5	63.4	62.8	56.4	45.2	35.3	28.6	44.8
Jackson	17	31.8	31.2	41.9	48.6	57.0	60.3	67.5	66.8	61.3	48.3	38.8	32.0	48.8
Johnsonville	19	29.2	28.2	39.5	46.1	55.2	62.8	66.4	65.8	59.4	46.4	36.2	29.4	47.0
Knoxville	39	30.5	32.2	39.5	47.5	56.1	64.2	67.6	66.4	60.6	48.1	38.0	31.9	48.6
Lynnville	19	31.5	30.0	40.7	46.7	56.6	64.5	67.8	66.9	61.3	48.9	38.4	32.0	48.8
Memphis	45	33.7	35.7	44.2	53.4	61.8	69.7	72.8	71.2	64.9	53.8	43.2	36.1	53.4
Mountain City	16	25.0	23.4	33.9	38.2	48.2	55.6	59.6	58.7	53.0	41.0	30.4	24.8	41.0
Nashville	42	31.0	32.4	40.4	49.7	58.6	66.9	70.2	68.7	61.9	50.2	39.8	33.2	50.2
Rugby	17	26.1	24.3	36.1	40.2	49.9	57.6	61.8	60.8	54.3	41.3	31.9	25.9	42.5
Savannah	19	32.6	31.6	42.3	48.3	57.1	64.7	68.4	67.6	61.1	48.3	39.2	32.9	49.5
Springdale	14	26.9	26.1	36.7	40.5	51.7	59.7	63.6	63.9	56.0	41.8	31.5	26.0	43.7
Trenton	18	30.2	28.8	41.1	48.2	57.3	63.8	66.9	66.6	59.8	47.0	37.3	30.4	48.1
Tullahoma	18	30.2	29.0	40.4	45.5	54.0	62.0	65.4	64.9	58.8	46.1	35.7	30.3	46.9
In Other States														
Atlanta, Ga.	34	35.1	36.7	44.0	51.5	60.1	67.0	69.7	68.9	64.2	53.5	43.5	36.5	52.6
Bismarck, N. Dak.	42	—3.7	—0.5	13.2	31.6	42.3	52.3	57.0	54.6	44.7	33.0	17.1	5.3	28.9
Columbia, Mo.	27	20.6	20.6	32.0	43.9	53.4	62.4	65.6	64.0	57.5	45.2	33.4	24.0	43.6
Dodge City, Kans.	36	17.1	19.7	29.4	40.9	51.0	60.6	65.4	64.5	55.8	43.0	29.1	21.2	41.5
Fort Worth, Texas	19	36.4	35.7	46.8	53.7	62.1	70.2	73.2	73.4	67.0	55.6	45.4	36.7	54.8
Indianapolis, Ind.	45	21.4	22.5	31.9	43.4	53.8	62.7	66.6	64.4	57.4	46.1	34.3	24.9	44.1
New Orleans, La.	43	46.9	48.8	55.2	61.2	67.7	73.7	75.5	75.4	72.6	63.5	54.3	47.9	61.8
Parkersburg, W. Va.	29	25.5	24.0	33.5	42.8	52.6	61.0	64.8	63.2	56.9	44.5	35.1	27.5	44.3

TABLE VI—AVERAGE PRECIPITATION

Stations	Length of Record, yrs.	Jan.	Feb.	Mch.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	An'l
Carthage	22	4.34	4.54	5.30	4.23	3.85	4.64	4.47	4.16	3.02	2.54	3.76	4.18	49.03
Chattanooga	38	5.17	4.97	5.63	4.64	3.82	4.16	4.23	3.85	3.37	2.82	3.25	4.83	50.74
Clarksville	56	4.29	4.21	5.01	4.72	4.06	3.99	3.88	3.32	2.83	2.40	4.10	4.62	47.43
Decatur	18	4.51	5.48	6.76	5.33	4.29	5.02	5.18	4.46	3.56	2.93	3.16	5.57	56.25
Florence	34	4.51	4.63	5.34	4.20	4.02	3.91	4.22	3.69	3.34	2.41	3.52	4.17	47.96
Greeneville	27	3.21	4.01	4.87	3.41	3.79	4.66	4.22	4.57	2.22	2.39	2.47	2.98	42.80
Jackson	25	4.14	3.52	4.59	5.47	4.07	4.36	4.38	3.51	2.67	2.57	3.92	5.11	48.31
Johnsonville	32	4.47	4.28	4.56	4.72	4.04	3.84	4.26	3.83	3.39	2.45	4.23	4.46	48.53
Knoxville	48	4.70	4.67	5.10	4.44	3.80	4.29	4.26	3.94	2.92	2.52	3.31	4.22	48.17
Lynnville	26	4.70	5.30	5.79	4.83	4.33	4.42	5.54	4.20	3.84	2.65	3.33	4.90	53.83
Memphis	53	5.00	4.59	5.25	4.93	4.28	4.03	3.18	3.54	2.84	2.64	4.36	4.39	49.03
Mountain City	17	3.57	3.63	4.84	3.85	4.25	5.28	5.89	5.28	3.17	2.83	2.30	3.61	48.50
Nashville	53	4.70	4.34	4.96	4.41	3.83	4.23	4.15	3.54	3.70	2.45	3.61	3.88	47.80
Rugby	26	5.12	5.20	6.17	5.02	4.32	4.61	5.29	4.29	3.53	2.29	3.46	4.50	53.80
Savannah	33	4.74	4.89	5.57	4.51	4.10	4.47	4.37	3.59	3.30	3.27	3.73	5.22	50.76
Springdale	23	4.00	4.93	4.86	4.08	3.76	4.15	5.42	4.53	2.78	2.46	3.37	3.97	48.31
Trenton	36	5.03	4.31	4.86	4.76	3.73	3.86	3.19	3.43	2.91	2.80	4.54	4.44	47.86
Tullahoma	27	5.26	4.62	5.91	4.70	3.62	4.15	5.00	3.95	3.36	2.79	3.44	5.59	52.39
In Other States														
Atlanta, Ga.	37	4.69	4.73	5.48	3.54	3.31	3.99	4.85	4.36	3.26	2.58	2.99	4.45	48.40
Bismarck, N. Dak.	42	0.53	0.49	1.03	1.64	2.48	3.60	2.26	2.04	1.28	1.00	0.64	0.58	17.57
Columbia, Mo.	19	2.46	2.18	2.91	3.88	4.83	4.86	4.08	3.58	3.84	2.16	2.15	1.70	38.46
Dodge City, Kans.	42	0.45	0.68	0.74	1.77	3.08	3.17	2.89	2.45	1.86	1.35	0.59	0.57	19.60
Fort Worth, Texas	23	1.79	2.11	2.53	3.68	4.79	3.31	3.23	2.04	2.58	2.90	2.63	1.77	33.36
Indianapolis, Ind.	46	3.11	2.97	3.86	3.35	3.89	4.05	4.16	3.26	3.01	2.68	3.36	2.90	40.84
New Orleans, La.	70	4.50	4.21	4.60	4.61	4.24	5.45	6.60	5.73	4.70	3.37	3.71	4.65	56.26
Parkersburg, W. Va.	24	3.37	3.29	3.69	3.06	3.40	4.38	4.53	3.39	2.70	2.25	2.67	2.66	39.39

TABLE I—MEAN TEMPERATURE

Stations	Length of Record, yrs.	Jan.	Feb.	Mch.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	An'l
Carthage	32	38.3	40.2	49.4	58.9	67.4	75.1	77.6	76.8	71.8	59.8	48.6	40.0	58.7
Chattanooga	35	41.8	43.6	51.9	59.6	68.7	75.6	78.4	77.5	72.1	61.3	50.8	42.9	60.4
Clarksville	52	38.0	39.1	48.1	58.0	66.3	74.0	77.6	76.1	70.4	58.1	47.3	39.5	57.7
Decatur	18	40.0	40.0	51.7	58.0	67.9	74.6	77.7	77.3	71.6	59.8	48.3	39.9	58.9
Florence	34	39.0	40.7	49.5	59.0	67.5	75.2	77.5	76.6	71.6	59.7	48.8	40.7	58.8
Greeneville	23	35.4	39.1	47.2	56.1	64.7	72.0	74.6	73.4	69.0	56.9	46.5	39.0	56.2
Jackson	23	40.8	41.3	51.8	60.6	68.9	76.8	79.4	78.8	73.4	60.7	50.7	41.3	60.4
Johnsonville	20	40.0	39.5	51.2	59.2	68.5	75.6	78.9	78.3	72.7	60.4	49.4	39.8	59.5
Knoxville	43	38.5	41.2	49.1	57.9	66.9	74.0	77.0	75.9	70.5	58.8	47.5	39.8	58.1
Lynnville	28	39.3	40.4	49.5	58.2	66.8	74.9	77.4	77.2	71.2	59.6	48.7	41.1	58.7
Memphis	45	40.4	42.5	52.4	61.9	70.4	77.9	80.7	79.4	73.5	62.7	51.6	43.3	61.4
Mountain City	17	35.5	33.7	45.6	50.6	61.3	67.1	70.2	68.9	63.9	53.3	42.4	34.9	52.3
Nashville	45	38.9	40.9	49.5	59.2	68.3	76.1	79.2	78.0	71.9	60.5	48.9	40.9	59.4
Rugby	26	35.0	36.5	46.8	54.5	64.0	71.3	74.1	73.1	67.7	54.9	44.7	37.3	55.1
Savannah	30	41.0	42.2	51.8	60.5	68.8	75.9	79.0	78.3	72.3	60.4	50.2	42.0	60.2
Springdale	20	37.6	39.2	49.1	56.6	66.2	74.0	76.4	76.0	70.0	56.7	45.9	36.8	57.0
Trenton	33	38.6	40.0	49.5	59.6	67.6	75.0	78.0	77.3	71.4	59.3	48.2	39.7	58.7
Tullahoma	27	38.4	39.3	49.3	57.7	66.1	73.1	76.3	75.6	70.3	58.3	47.3	39.9	57.6
In Other States														
Atlanta, Ga.	25	42.9	43.3	53.0	60.4	70.0	76.2	78.1	77.6	73.3	62.4	52.1	43.7	61.1
Bismarck, N. Dak.	42	6.7	9.9	23.5	43.2	54.1	63.6	69.4	67.4	57.6	45.0	27.7	15.2	40.3
Columbia, Mo.	27	30.2	30.3	42.6	54.9	64.5	73.1	76.9	76.0	68.9	57.2	44.2	33.4	54.4
Dodge City, Kans.	31	27.3	31.1	41.7	54.4	63.5	73.1	77.7	76.5	68.2	54.7	40.5	31.6	53.3
Fort Worth, Texas	19	47.0	46.8	57.8	64.1	71.8	80.3	83.1	83.5	77.4	66.7	56.8	46.3	65.2
Indianapolis, Ind.	45	28.7	30.2	40.0	52.5	63.1	72.0	76.1	73.9	67.0	55.3	41.9	32.1	52.8
New Orleans, La.	46	54.3	56.7	62.8	68.8	75.2	80.7	82.3	82.2	79.0	70.5	61.7	55.4	69.1
Parkersburg, W. Va.	29	33.4	32.3	42.8	53.1	63.4	71.4	75.2	73.6	67.8	55.4	44.1	35.1	54.0

TABLE II—Highest Temperature

Stations	Length of Record, yrs.	Jan.	Feb.	Mch.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	An'l
Carthage	32	76	82	90	92	98	104	103	101	102	96	85	74	104
Chattanooga	35	75	78	89	90	95	100	101	101	98	92	81	73	101
Clarksville	26	75	79	87	92	98	107	108	107	105	93	85	73	108
Decatur	18	76	75	91	89	96	100	104	101	100	96	79	72	104
Florence	32	74	75	86	88	94	100	100	100	98	93	79	71	100
Greeneville	23	73	78	82	88	91	95	97	97	96	90	78	69	97
Jackson	13	79	83	82	90	102	104	103	104	103	98	85	72	104
Johnsonville	22	78	80	90	92	100	105	107	103	103	96	88	73	107
Knoxville	43	74	79	87	90	95	99	100	100	99	94	80	75	100
Lynnville	19	73	75	85	91	93	100	102	99	97	94	79	73	102
Memphis	43	79	79	87	90	97	100	104	102	99	92	82	76	104
Mountain City	17	74	71	82	85	89	91	92	93	88	87	78	72	93
Nashville	45	76	77	89	90	96	100	102	104	99	92	81	75	104
Rugby	26	73	76	88	88	95	99	100	98	98	89	80	70	100
Savannah	30	76	77	87	90	96	104	105	104	103	94	84	78	105
Springdale	15	75	77	88	92	95	99	100	100	104	88	79	73	104
Trenton	30	76	80	86	90	100	106	103	100	103	95	85	75	105
Tullahoma	27	74	73	86	90	94	99	100	100	97	91	79	70	100
In Other States														
Atlanta, Ga.	37	75	78	87	89	97	100	100	98	97	94	82	73	100
Bismarck, N. Dak.	42	60	64	81	90	96	103	107	105	102	91	73	64	107
Columbia, Mo.	27	77	81	92	91	96	104	111	105	104	95	84	75	111
Dodge City, Kans.	42	76	83	98	95	101	107	108	105	101	92	85	79	108
Fort Worth, Texas	19	93	96	100	97	103	105	109	112	104	99	87	83	112
Indianapolis, Ind.	45	70	72	84	87	96	100	106	101	98	89	76	68	106
New Orleans, La.	46	82	82	86	90	96	102	102	100	98	94	89	83	102
Parkersburg, W. Va.	29	74	76	86	93	96	99	102	98	99	90	78	72	102

TABLE V—MEAN MINIMUM TEMPERATURE

Stations	Length of Record, yrs.	Jan.	Feb.	Mch.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	An'l
Carthage	17	30.5	28.8	39.9	46.3	55.9	63.6	65.6	66.0	60.6	48.6	37.8	30.3	47.9
Chattanooga	35	33.4	34.8	42.5	50.3	58.0	65.8	69.1	68.3	62.7	51.0	41.0	34.6	51.0
Clarksville	18	30.2	28.4	40.4	47.1	57.0	65.0	68.7	67.4	61.5	48.6	38.2	30.6	48.6
Decatur	18	29.6	28.8	39.7	44.8	54.2	62.0	65.8	65.1	58.6	45.6	35.1	29.7	46.6
Florence	19	31.3	30.1	40.9	47.4	57.1	65.1	68.2	67.3	61.4	48.9	38.4	31.6	49.0
Greeneville	10	26.7	26.2	38.5	41.9	52.6	60.5	63.4	62.8	56.4	45.2	35.3	28.6	44.8
Jackson	17	31.8	31.2	41.9	48.6	57.0	60.3	67.5	66.8	61.3	48.3	38.8	32.0	48.8
Johnsonville	19	29.2	28.2	39.5	46.1	55.2	62.8	66.4	65.8	59.4	46.4	36.2	29.4	47.0
Knoxville	39	30.5	32.2	39.5	47.5	56.1	64.2	67.6	66.4	60.6	48.1	38.0	31.9	48.6
Lynnville	19	31.5	30.0	40.7	46.7	56.6	64.5	67.8	66.9	61.3	48.9	38.4	32.0	48.8
Memphis	45	33.7	35.7	44.2	53.4	61.8	69.7	72.8	71.2	64.9	53.8	43.2	36.1	53.4
Mountain City	16	25.0	23.4	33.9	38.2	48.2	55.6	59.6	58.7	53.0	41.0	30.4	24.8	41.0
Nashville	42	31.0	32.4	40.4	49.7	58.6	66.9	70.2	68.7	61.9	50.2	39.8	33.2	50.2
Rugby	17	26.1	24.3	36.1	40.2	49.9	57.6	61.8	60.8	54.3	41.3	31.9	25.9	42.5
Savannah	19	32.6	31.6	42.3	48.3	57.1	64.7	68.4	67.6	61.1	48.3	39.2	32.9	49.5
Springdale	14	26.9	26.1	35.7	40.5	51.7	59.7	63.6	63.9	56.0	41.8	31.5	26.0	43.7
Trenton	18	30.2	28.8	41.1	48.2	57.3	63.8	66.9	66.6	59.8	47.0	37.3	30.4	48.1
Tullahoma	18	30.2	29.0	40.4	45.5	54.0	62.0	65.4	64.9	58.8	46.1	35.7	30.3	46.9
In Other States														
Atlanta, Ga.	34	35.1	36.7	44.0	51.5	60.1	67.0	69.7	68.9	64.2	53.5	43.5	36.5	52.6
Bismarck, N. Dak.	42	—3.7	—0.5	13.2	31.6	42.3	52.3	57.0	54.6	44.7	33.0	17.1	5.3	28.9
Columbia, Mo.	27	20.6	20.6	32.0	43.9	53.4	62.4	65.6	64.0	57.5	45.2	33.4	24.0	43.6
Dodge City, Kans.	36	17.1	19.7	29.4	40.9	51.0	60.6	65.4	64.5	55.8	43.0	29.1	21.2	41.5
Fort Worth, Texas	19	36.4	35.7	46.8	53.7	62.1	70.2	73.2	73.4	67.0	55.6	45.4	36.7	54.8
Indianapolis, Ind.	45	21.4	22.5	31.9	43.4	53.8	62.7	66.6	64.4	57.4	46.1	34.3	24.9	44.1
New Orleans, La.	43	46.9	48.8	55.2	61.2	67.7	73.7	75.5	75.4	72.6	63.5	54.3	47.9	61.8
Parkersburg, W. Va.	29	25.5	24.0	33.5	42.8	52.6	61.0	64.8	63.2	56.9	44.5	35.1	27.5	44.3

TABLE VI—AVERAGE PRECIPITATION

Stations	Length of Record, yrs.	Jan.	Feb.	Mch.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	An'l
Carthage	22	4.34	4.54	5.30	4.23	3.85	4.64	4.47	4.16	3.02	2.54	3.76	4.18	49.03
Chattanooga	38	5.17	4.97	5.63	4.64	3.82	4.16	4.23	3.85	3.37	2.82	3.25	4.83	50.74
Clarksville	56	4.29	4.21	5.01	4.72	4.06	3.99	3.88	3.32	2.83	2.40	4.10	4.62	47.43
Decatur	18	4.51	5.48	6.76	5.33	4.29	5.02	5.18	4.46	3.56	2.93	3.16	5.57	56.25
Florence	34	4.51	4.63	5.34	4.20	4.02	3.91	4.22	3.69	3.34	2.41	3.52	4.17	47.96
Greeneville	27	3.21	4.01	4.87	3.41	3.79	4.66	4.22	4.57	2.22	2.39	2.47	2.98	42.80
Jackson	25	4.14	3.52	4.59	5.47	4.07	4.36	4.38	3.51	2.67	2.57	3.92	5.11	48.31
Johnsonville	32	4.47	4.28	4.56	4.72	4.04	3.84	4.26	3.83	3.39	2.45	4.23	4.46	48.53
Knoxville	48	4.70	4.67	5.10	4.44	3.80	4.29	4.26	3.94	2.92	2.52	3.31	4.22	48.17
Lynnville	26	4.70	5.30	5.79	4.83	4.33	4.42	5.54	4.20	3.84	2.65	3.33	4.90	53.83
Memphis	53	5.00	4.59	5.25	4.93	4.28	4.03	3.18	3.54	2.84	2.64	4.36	4.39	49.03
Mountain City	17	3.57	3.63	4.84	3.85	4.25	5.28	5.89	5.28	3.17	2.83	2.30	3.61	48.50
Nashville	53	4.70	4.34	4.96	4.41	3.83	4.23	4.15	3.54	3.70	2.45	3.61	3.88	47.80
Rugby	26	5.12	5.20	6.17	5.02	4.32	4.61	5.29	4.29	3.53	2.29	3.46	4.50	53.80
Savannah	33	4.74	4.89	5.57	4.51	4.10	4.47	4.37	3.59	3.30	3.27	3.73	5.22	50.76
Springdale	23	4.00	4.93	4.86	4.08	3.76	4.15	5.42	4.53	2.78	2.46	3.37	3.97	48.31
Trenton	36	5.03	4.31	4.86	4.76	3.73	3.86	3.19	3.43	2.91	2.80	4.54	4.44	47.86
Tullahoma	27	5.26	4.62	5.91	4.70	3.62	4.15	5.00	3.95	3.36	2.79	3.44	5.59	52.39
In Other States														
Atlanta, Ga.	37	4.69	4.73	5.48	3.54	3.31	3.99	4.85	4.36	3.26	2.58	2.99	4.45	48.40
Bismarck, N. Dak.	42	0.53	0.49	1.03	1.64	2.48	3.60	2.26	2.04	1.28	1.00	0.64	0.58	17.57
Columbia, Mo.	19	2.46	2.18	2.91	3.88	4.83	4.86	4.08	3.58	3.84	2.16	2.15	1.70	38.46
Dodge City, Kans.	42	0.45	0.68	0.74	1.77	3.08	3.17	2.89	2.45	1.86	1.35	0.59	0.57	19.60
Fort Worth, Texas	23	1.79	2.11	2.53	3.68	4.79	3.31	3.23	2.04	2.58	2.90	2.63	1.77	33.36
Indianapolis, Ind.	46	3.11	2.97	3.86	3.35	3.89	4.05	4.16	3.26	3.01	2.68	3.36	2.90	40.84
New Orleans, La.	70	4.50	4.21	4.60	4.61	4.24	5.45	6.60	5.73	4.70	3.37	3.71	4.65	56.26
Parkersburg, W. Va.	24	3.37	3.29	3.69	3.06	3.40	4.38	4.53	3.39	2.70	2.25	2.67	2.66	39.39

TABLE IX—MEMPHIS, TENN., MONTHLY AND ANNUAL PRECIPITATION

Year	Jan.	Feb.	Mch.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	An'l
1850	....	....	7.80	5.74	5.31	6.60	3.18	1.47	0.03	1.07	1.65	6.07	.....
1851	1.39	8.77	....	....	....	....	....	....	....	....	....	....	.....
.....	....	....	....	....	....	....	....	....	....	....	....	....	.....
1857	....	2.54	0.91	8.73	4.78	2.96	....	....	2.50	1.47	4.82	4.91	.....
1858	4.91	3.25	4.75	3.15	7.56	5.00	9.64	3.37	1.40	1.92	3.14	5.46	53.55
1859	4.05	7.10	6.41	6.40	....	....	1.75	4.48	4.76	1.48	3.77	3.47	.....
1860	7.20	5.46	0.88	3.62	0.50	5.60	2.57	1.09	2.95	3.52	4.15	....	.....
1861	1.30	3.05	3.65	....	....	....	....	....	....	....	....	....	.....
.....	....	....	....	....	....	....	....	....	....	....	....	....	.....
1867	....	....	....	....	....	....	....	....	2.23	1.87	3.59	1.81	.....
1868	5.30	1.28	4.17	7.96	3.44	1.53	2.74	6.35	9.31	1.97	2.13	4.27	50.45
1869	2.24	3.97	6.37	8.79	1.74	3.60	2.36	3.26	1.30	3.99	4.84	4.68	47.14
1870	4.96	4.69	5.65	....	....	....	....	....	....	....	....	....	.....
1871	....	....	9.84	5.03	6.02	5.12	2.53	2.69	3.38	4.04	2.23	1.70	.....
1872	2.17	4.24	5.19	6.99	4.16	4.44	4.23	0.54	3.62	3.23	1.67	3.47	43.95
1873	5.85	8.98	3.44	4.87	4.82	6.36	0.82	4.53	3.53	5.95	3.87	3.18	56.20
1874	2.88	4.10	6.61	10.16	0.63	2.22	0.47	4.60	5.99	1.07	3.86	3.12	45.71
1875	7.45	3.34	8.60	3.48	4.21	2.72	4.34	2.39	2.94	2.38	9.63	5.54	57.02
1876	7.65	1.33	11.03	4.51	8.49	2.70	4.38	5.37	3.04	3.95	0.90	2.14	55.49
1877	4.31	1.54	4.24	13.90	1.81	18.16	6.22	6.05	3.11	3.75	5.97	4.44	73.50
1878	4.11	5.08	3.80	11.93	3.66	5.47	2.40	1.72	2.59	2.91	2.45	3.21	49.33
1879	7.71	3.25	2.98	5.54	5.53	3.17	3.01	4.57	0.62	1.39	6.01	8.51	52.29
1880	6.87	9.44	8.82	3.91	3.82	4.96	2.14	3.03	2.47	5.20	8.39	2.62	61.67
1881	4.38	6.41	3.23	5.74	2.80	2.83	0.89	1.97	3.84	3.22	5.14	2.39	42.84
1882	12.87	9.92	9.10	3.56	9.14	4.15	4.13	3.49	2.18	4.08	6.65	1.78	71.05
1883	4.83	8.09	4.43	4.66	6.55	4.92	1.78	1.85	1.05	8.56	4.56	5.86	57.14
1884	5.66	9.64	5.08	8.60	6.46	7.26	2.38	1.27	4.29	2.83	2.08	9.14	64.69
1885	6.61	1.88	3.07	3.00	3.05	1.52	4.80	1.70	4.42	1.18	3.26	2.92	37.41
1886	4.55	6.43	3.00	2.88	2.11	8.06	5.52	6.49	6.20	0.59	8.89	3.00	57.72
1887	5.00	8.37	4.18	2.34	2.83	1.04	3.30	1.21	2.15	2.24	4.06	5.80	42.52
1888	4.04	2.49	5.40	1.15	2.35	4.32	2.12	10.44	1.06	3.51	6.53	3.41	46.82
1889	5.28	1.90	5.33	3.47	1.48	7.39	4.77	5.62	3.01	0.75	5.21	0.46	44.67
1890	8.43	8.13	7.93	5.10	4.42	3.55	2.82	7.56	9.07	2.75	4.88	3.64	68.28

1892	6.16	3.35	3.68	7.58	2.81	3.50	4.11	3.10	0.63	0.47	5.91	3.32	44.62
1893	1.56	7.96	2.49	5.46	6.71	4.92	5.25	2.08	1.45	1.73	1.32	2.49	43.42
1894	3.80	7.37	2.37	2.81	3.85	1.43	2.24	4.79	0.47	1.50	0.55	6.26	37.44
1895	6.72	1.95	4.65	3.36	5.63	3.39	4.50	1.89	0.59	1.24	1.90	2.93	38.75
1896	1.49	5.51	5.30	4.24	5.31	5.61	7.36	1.25	2.02	1.59	4.32	0.95	44.95
1897	2.91	4.66	9.59	6.26	6.11	3.18	3.83	5.23	1.92	1.97	1.87	5.42	52.95
1898	7.68	0.56	3.97	3.34	1.60	3.47	2.97	4.86	7.44	3.13	2.10	1.67	42.79
1899	3.70	6.21	11.28	2.68	3.58	3.71	3.93	1.52	1.68	2.53	0.89	2.70	44.41
1900	3.35	5.52	3.64	1.92	1.72	6.42	3.90	3.64	3.41	2.21	5.63	2.75	44.11
1901	4.31	0.79	4.32	5.35	4.03	6.44	0.69	10.48	4.13	1.57	1.30	12.34	55.75
1902	3.71	3.53	6.37	1.79	2.09	5.45	3.73	2.39	8.04	0.99	4.03	3.46	45.58
1903	2.10	8.35	6.96	7.21	3.09	3.39	2.26	3.86	0.62	1.88	4.19	1.98	45.89
1904	2.02	4.42	6.35	1.90	2.34	1.66	2.50	3.92	1.10	0.07	3.43	5.37	35.09
1905	3.24	5.68	3.86	4.36	3.80	3.55	3.23	7.35	0.55	4.55	1.27	5.16	46.60
1906	3.60	1.24	3.83	2.64	4.69	5.73	6.53	1.35	3.82	2.38	3.78	3.57	43.16
1907	1.29	3.19	5.17	3.79	3.54	4.28	3.04	2.16	6.89	0.93	5.80	3.72	43.80
1908	4.04	2.87	3.25	3.02	2.15	2.07	3.90	3.95	1.78	2.57	3.13	5.65	38.38
1909	3.17	7.05	5.98	5.70	4.14	9.68	7.01	3.17	2.91	1.61	0.91	2.49	53.82
1910	3.66	4.19	0.72	4.12	7.28	3.13	5.09	3.86	3.68	1.68	0.97	4.94	43.32
1911	4.79	4.83	3.99	7.66	1.23	2.72	4.31	2.99	1.89	3.78	4.37	4.84	47.40
1912	3.00	2.96	7.04	7.98	5.94	2.44	4.32	2.66	5.08	1.30	1.47	6.42	50.61
1913	8.93	4.51	6.43	2.00	4.86	1.56	3.77	1.44	3.34	2.45	1.11	3.59	43.99
1914	1.64	3.47	3.97	4.50	1.25	3.91	7.11	5.69	1.04	3.57	1.29	7.86	45.30
1915	4.18	3.37	2.57	1.45	3.59	6.24	3.72	3.95	4.04	2.68	5.48	7.77	49.04
1916	5.23	3.33	2.25	2.03	4.71	5.29	6.48	4.24	2.84	1.97	2.55	3.63	44.55
Means	4.70	4.67	5.10	4.44	3.80	4.29	4.26	3.94	2.92	2.52	3.31	4.22	48.17

TABLE X—NASHVILLE, TENN., MONTHLY AND ANNUAL PRECIPITATION

Year	Jan.	Feb.	Mch.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	An'l
1839	....	....	....	....	....	1.50	1.00	0.50	4.00	0.10	3.64	2.76	.....
1840	3.05	4.87	4.05	11.82	6.55	5.72	5.05	4.90	3.04	6.83	2.19	1.07	59.14
1841	9.09	2.25	4.89	4.38	4.50	4.42	5.47	8.58	5.70	5.45	2.95	4.02	61.70
1842	5.56	7.30	5.63	4.15	6.48	4.81	2.73	4.50	5.09	1.29	3.01	3.04	53.59
1843	3.79	2.93	4.29	4.65	4.04	4.87	4.23	5.94	8.61	5.09	6.16	3.71	58.31
1844	3.54	2.57	5.66	1.00	3.15	5.16	4.57	1.39	3.23	3.30	5.54	3.16	42.27
1845	5.01	3.98	4.90	5.20	4.94	5.00	4.41	5.06	5.13	4.39	3.97	3.00	54.99
.....	....	....	....	....	....	....	....	....	....	....	....	....	.....
1850	5.49	5.92	5.42	1.07	....	4.98	5.00	3.55	1.15	....	....	....	.....
.....	....	....	....	....	....	....	....	....	....	....	....	....	.....
1871	2.76	4.58	5.01	4.13	3.30	2.98	1.58	2.36	0.95	1.31	2.13	1.65	32.74
1872	2.32	2.11	3.14	5.91	3.09	5.17	6.10	1.65	4.50	1.58	2.25	2.38	40.20
1873	2.96	7.14	4.11	3.59	6.31	4.20	4.63	2.36	1.81	4.28	4.36	5.94	51.69
1874	5.22	9.23	5.36	11.84	1.49	2.87	2.65	3.52	3.12	2.63	6.12	4.19	58.24
1875	6.15	3.06	8.14	4.25	1.73	5.63	8.12	1.60	3.79	1.25	5.46	4.30	53.48
1876	6.41	2.22	5.28	3.62	3.40	5.65	7.15	5.77	2.52	2.68	1.26	0.95	46.91
1877	4.05	1.06	4.95	9.47	1.25	6.02	3.25	4.16	5.40	2.61	4.93	2.49	49.64
1878	3.34	2.11	3.48	6.88	2.33	3.28	9.43	5.02	1.28	2.17	3.20	6.04	48.56
1879	6.32	3.13	3.81	2.88	2.88	2.50	8.47	4.62	5.18	2.90	5.85	9.15	57.69
1880	3.74	12.37	8.16	5.26	4.13	3.95	5.69	2.22	5.39	7.24	5.77	3.32	67.24
1881	3.54	5.48	2.79	5.12	3.67	3.70	0.86	1.81	6.57	4.80	4.89	4.85	48.08
1882	14.51	8.61	9.38	3.59	7.38	2.54	4.06	5.54	1.61	1.11	3.60	1.52	63.45
1883	3.76	7.90	3.98	9.12	4.82	3.82	4.88	4.47	2.23	5.27	3.11	4.97	58.33
1884	7.20	8.18	8.89	3.51	3.58	6.53	3.18	2.81	2.36	2.43	1.57	3.78	54.02
1885	6.29	2.00	2.33	3.75	4.36	3.72	5.26	1.02	5.60	2.99	2.73	2.90	42.95
1886	5.18	3.82	4.76	2.36	2.10	7.69	1.90	5.50	3.68	0.51	5.76	1.48	44.74
1887	5.13	8.47	3.36	2.67	3.43	2.31	3.77	2.89	6.85	1.92	2.29	5.31	48.40
1888	6.29	3.78	6.46	4.18	2.97	4.68	2.36	7.03	3.82	2.82	4.33	1.77	50.49
1889	3.83	1.84	2.47	2.83	5.00	5.33	2.74	1.57	6.81	1.54	6.88	1.17	42.01
1890	8.10	10.95	8.64	3.84	4.16	2.23	0.46	6.59	5.86	3.01	2.01	4.12	59.97
1891	6.15	6.96	10.31	2.24	2.39	6.50	1.49	3.72	1.25	0.84	6.71	4.26	52.82
1892	2.81	2.73	4.10	7.45	4.03	5.01	5.13	3.39	4.78	0.25	3.91	6.43	50.02
1893	1.27	4.88	3.37	4.11	7.31	4.74	2.12	1.92	6.43	3.68	2.97	3.50	46.30

1894	4.28	8.65	2.69	4.05	2.53	3.55	5.45	2.43	3.07	0.53	1.92	2.81	41.96
1895	5.71	0.98	5.09	3.07	2.05	2.90	7.14	1.40	6.69	1.57	2.14	4.09	42.83
1896	1.37	3.65	6.45	2.92	4.05	1.82	7.33	1.40	2.74	0.98	5.71	1.79	40.21
1897	3.13	3.84	8.49	5.79	1.22	1.82	8.53	2.34	0.19	0.92	2.83	4.93	44.03
1898	9.46	0.63	5.36	3.16	1.80	4.97	4.50	6.56	4.87	3.21	3.09	2.41	50.02
1899	5.59	5.19	7.81	3.25	3.36	0.75	6.44	2.53	1.50	1.83	1.55	4.64	44.44
1900	2.61	3.80	2.20	4.04	1.86	10.35	2.87	1.24	4.55	3.93	8.87	2.22	48.54
1901	3.45	1.60	2.39	4.99	4.11	0.48	2.59	8.24	4.27	0.63	0.85	4.51	38.11
1902	4.68	2.20	6.96	3.08	4.36	2.77	1.89	2.69	2.82	1.83	4.04	6.58	43.90
1903	1.80	4.81	5.17	4.00	5.64	7.58	3.04	1.42	0.13	2.06	3.47	3.91	43.03
1904	3.93	1.24	5.20	2.35	2.97	6.38	4.62	2.80	0.81	0.29	1.66	5.01	37.26
1905	3.17	2.66	5.10	1.50	6.00	7.31	3.23	2.97	6.12	3.56	1.35	4.15	47.12
1906	3.26	0.79	6.49	1.75	3.80	2.62	3.61	2.94	10.95	2.28	5.88	5.11	49.48
1907	2.60	3.53	3.58	4.66	6.01	2.67	0.80	2.53	1.95	2.01	4.39	2.69	37.42
1908	3.02	4.15	4.16	4.43	2.80	2.73	3.32	1.69	1.89	0.44	3.31	2.10	34.04
1909	2.34	7.08	4.94	4.12	4.57	5.56	4.93	2.73	4.23	1.01	2.58	2.90	46.99
1910	3.45	4.87	0.85	6.10	5.81	6.61	4.45	1.73	0.74	3.20	1.17	3.92	42.90
1911	2.00	4.68	2.22	5.11	1.67	4.58	3.34	5.17	1.89	2.21	4.38	11.01	48.26
1912	2.92	4.21	6.00	11.73	4.02	5.66	5.37	3.05	2.46	2.45	0.65	5.14	53.67
1913	12.30	4.71	5.54	1.65	2.66	0.90	4.09	0.85	1.79	2.93	1.84	2.45	40.71
1914	1.56	2.03	4.33	3.83	3.01	2.95	2.58	8.64	1.46	2.80	2.13	5.06	40.38
1915	5.89	1.01	2.14	0.72	4.94	1.42	2.03	6.03	4.63	0.42	6.75	6.44	42.42
1916	7.62	1.19	3.60	2.49	5.37	4.62	4.17	4.27	1.92	2.67	1.00	4.29	43.21
Means	4.70	4.34	4.96	4.41	3.83	4.23	4.15	3.54	3.70	2.45	3.61	3.88	47.80

TABLE XI—Average Number of Days with 0.01 Inch or More of Precipitation

Stations	Length of Record, yrs.	Jan.	Feb.	Mch.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	An'l
Carthage	33	11	11	12	11	10	12	11	9	7	7	8	11	120
Chattanooga	35	13	12	13	11	10	13	13	12	9	7	9	12	134
Clarksville	24	10	10	12	11	10	8	8	8	6	6	7	10	106
Decatur	18	12	11	13	11	10	13	14	11	8	7	9	13	132
Florence	32	10	9	10	10	9	10	10	8	7	6	7	9	105
Greeneville	23	12	11	12	10	12	11	13	11	7	7	7	10	123
Jackson	15	9	11	11	11	9	9	8	9	7	7	7	9	107
Johnsonville	21	11	10	11	10	10	10	10	9	6	6	8	10	111
Knoxville	43	13	11	13	12	12	13	12	12	8	7	9	13	135
Lynnville	26	8	8	9	9	8	9	10	8	6	4	6	8	93
Memphis	45	11	10	12	10	10	10	10	8	7	6	9	11	114
Mountain City	16	12	11	12	12	13	14	14	13	9	7	8	12	137
Nashville	45	12	11	12	11	10	11	11	9	8	6	9	11	121
Rugby	24	10	9	10	10	10	10	10	8	6	5	6	9	103
Savannah	15	9	7	11	9	9	8	8	7	6	5	6	8	93
Springdale	15	11	10	11	11	9	9	11	9	6	5	7	11	110
Trenton	29	8	8	9	8	8	8	7	6	6	5	7	8	88
Tullahoma	25	10	9	11	9	9	10	10	9	7	6	7	11	108
In Other States														
Atlanta, Ga.	34	12	11	11	10	9	11	12	13	8	7	9	11	124
Bismarck, N. Dak.	42	6	5	7	7	10	12	9	8	7	5	4	6	86
Columbia, Mo.	27	8	9	10	12	13	12	9	9	9	8	7	8	114
Dodge City, Kans.	36	4	5	6	7	10	9	9	7	5	5	4	4	75
Fort Worth, Texas	19	5	5	7	8	9	6	6	5	5	5	6	6	75
Indianapolis, Ind.	45	15	5	11	12	18	14	8	8	8	9	6	12	126
New Orleans, La.	46	10	9	9	7	9	13	15	14	11	6	7	11	121
Parkersburg, W. Va.	29	15	13	15	13	12	14	12	10	9	9	10	13	145

TABLE XII—Precipitation, Special Features of

Stations	Average annual No. days .01 to .25 inch.	.26 to 1.0 inch.	More than 2.0 inches	With more than 1.0 inch an hour.	Absolute maximum in 24 hours, inches.	Absolute maximum in one hour, inches.	Average date of first snow in autumn.	Average date of last snow in spring.	Av. annual duration of measurable snow, days.
Chattanooga, Tenn.	80	40	2	2	6.60	2.57	Nov. 21	March 18	5
Knoxville, Tenn.	74	43	2	1	5.68	2.01	Nov 22	March 29	7
Memphis, Tenn.	59	37	3	1	9.67	2.34	Dec. 8	March 3	4
Nashville, Tenn.	66	38	2	3	6.05	2.25	Nov. 22	March 27	9
Atlanta, Ga.	79	39	3	2	7.36	2.40	Dec. 2	March 10	2
Bismarck, N. Dak.	67	17	0	1	3.76	2.96	Oct. 15	April 28	98
Columbia, Mo.	70	33	2	3	6.13	2.80	Nov. 7	April 5	34
Dodge City, Kans.	56	17	1	1	6.03	4.81	Nov. 1	March 22	20
Fort Worth, Texas	35	21	2	3	7.44	3.07	Dec. 13	Feb. 24	3
Indianapolis, Ind.	77	39	1	2	6.80	2.59	Nov. 5	April 11	37
Minneapolis, Minn.	73	33	2	1	4.96	2.62	Oct. 25	April 22	87
New Orleans, La.	64	36	4	7	8.76	3.01	.....	.....	0
Parkersburg, W. Va.	91	42	1	1	3.76	2.12	Nov. 10	April 12	32

TABLE XVI—First and Last Killing Frost.

Stations	Length of record, years	Average date of first killing frost in autumn	Average date of last killing frost in spring	Earliest date of killing frost in autumn	Latest date of killing frost in spring	Average growing season (days)
Carthage	16	Oct. 28	April 7	Oct. 11	April 25	204
Chattanooga	35	Oct. 26	April 2	Sept. 30	May 14	207
Clarksville	23	Oct. 24	April 5	Oct. 1	May 1	202
Decatur	17	Oct. 23	April 18	Oct. 11	May 10	188
Florence	23	Oct. 23	April 4	Oct. 1	April 21	202
Greeneville	14	Oct. 19	April 19	Sept. 30	May 15	183
Jackson	22	Oct. 23	April 2	Oct. 2	May 2	204
Johnsonville	20	Oct. 21	April 8	Sept. 22	May 2	196
Knoxville	43	Oct. 28	April 2	Oct. 1	April 24	209
Lynnville	23	Oct. 21	April 7	Sept. 27	April 27	197
Memphis	44	Nov. 2	Mar. 22	Oct. 2	April 25	225
Mountain City	15	Oct. 13	April 30	Sept. 27	May 22	166
Nashville	45	Oct. 27	April 1	Oct. 8	April 24	209
Rugby	20	Oct. 13	April 26	Sept. 18	May 15	170
Savannah	22	Oct. 25	April 3	Sept. 30	May 2	205
Springdale	18	Oct. 15	April 24	Sept. 30	May 21	174
Trenton	22	Oct. 19	April 3	Sept. 30	May 2	199
Tullahoma	22	Oct. 19	April 11	Sept. 27	May 10	191
In Other States						
Atlanta, Ga.	27	Nov. 5	Mar. 24	Oct. 11	April 17	226
Bismarck, N. Dak.	43	Sept. 21	May 11	Aug. 23	June 7	133
Columbia, Mo.	27	Oct. 14	April 12	Sept. 18	May 9	185
Dodge City, Kans.	41	Oct. 16	April 17	Sept. 23	May 27	182
Fort Worth, Tex.	25	Nov. 18	Mar. 14	Oct. 22	April 3	249
Indianapolis, Ind.	39	Oct. 19	April 16	Sept. 21	May 14	186
New Orleans, La.	44	Dec. 16	Jan. 25	Nov. 11	Mar. 27	325
Park'sburg, W. Va.	30	Oct. 14	April 16	Sept. 29	May 22	181

TABLE XIII—SNOWFALL, AVERAGE MONTHLY IN INCHES

Stations	Length of Record, yrs.	Jan.	Feb.	Mch.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	An'l
Carthage	32	2.5	3.3	1.8	0.3	0	0	0	0	0	T	0.1	1.1	9.1
Chattanooga	35	2.1	2.6	0.4	0.2	0	0	0	0	0	T	0.3	1.2	6.9
Clarksville	24	4.4	4.0	2.5	0.5	T	0	0	0	0	0.1	0.4	2.7	14.6
Decatur	18	1.7	3.1	0.6	T	0	0	0	0	0	T	0.6	1.1	7.1
Florence	29	2.7	3.0	1.9	0.2	0	0	0	0	0	T	0.2	1.3	9.3
Greeneville	23	4.5	4.2	1.8	1.9	T	0	0	0	0	T	1.5	4.4	18.3
Jackson	15	1.8	2.0	0.3	T	0	0	0	0	0	T	0.2	2.0	6.3
Johnsonville	18	3.0	2.7	0.5	T	0	0	0	0	0	T	0.3	1.4	7.9
Knoxville	28	3.0	3.0	0.8	0.3	T	0	0	0	0	T	0.4	1.9	9.4
Lynnville	26	2.1	2.7	1.2	T	0	0	0	0	0	T	0.4	0.9	7.3
Memphis	31	2.1	1.8	0.9	0	0	0	0	0	0	0	T	1.4	6.2
Mountain City	16	6.6	5.0	3.0	1.4	T	0	0	0	0	0.2	1.8	4.7	22.7
Nashville	31	2.5	3.1	1.7	0.1	T	0	0	0	0	T	0.2	1.1	8.7
Rugby	24	5.1	5.9	2.6	0.8	T	0	0	0	0	T	1.5	3.3	19.2
Savannah	16	1.3	1.5	0.4	T	0	0	0	0	0	T	T	1.5	4.7
Springdale	18	4.6	4.0	1.2	0.5	T	0	0	0	0	T	1.0	2.7	14.0
Trenton	25	3.2	3.2	0.8	T	0	0	0	0	0	0.1	0.4	1.4	9.1
Tullahoma	25	2.7	2.9	1.7	0.2	0	0	0	0	0	T	0.5	1.8	9.8
In Other States														
Atlanta, Ga.	27	1.2	1.3	0.1	0.1	0	0	0	0	0	T	0.1	0.5	3.3
Bismarck, N. Dak.	25	5.4	4.5	8.7	2.9	0.8	0	0	0	0.1	1.0	5.5	5.7	34.5
Columbia, Mo.	27	5.4	7.3	4.2	0.5	T	0	0	0	0	0.1	0.7	4.4	22.6
Dodge City, Kans.	26	4.8	7.3	4.5	1.1	T	0	0	0	0	0.3	1.4	4.2	23.6
Fort Worth, Texas	19	0.8	0.6	0.2	0	0	0	0	0	0	0	T	0.6	2.4
Indianapolis, Ind.	32	6.4	6.0	4.1	0.9	0.1	0	0	0	0	T	1.2	5.2	23.9
New Orleans, La.	46	0.2	0.2	0	0	0	0	0	0	0	0	0	T	0.4
Parkersburg, W. Va.	29	7.9	7.9	5.3	1.0	T	0	0	0	0	T	1.4	5.3	28.8

T—Trace, amount too small to measure.

TABLE XIV—MEAN RELATIVE HUMIDITY (PERCENTAGES)

Stations	Length of Record, yrs.	Jan.	Feb.	Mch.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	An'l
Chattanooga, Tenn.	25	76	71	69	66	71	75	76	78	78	76	72	75	74
Knoxville, Tenn.	26	77	72	72	65	69	74	76	79	77	75	74	77	74
Memphis, Tenn.	28	73	70	70	66	71	73	75	76	74	71	70	74	72
Nashville, Tenn.	28	75	73	70	64	68	70	71	74	72	70	70	75	71
Atlanta, Ga.	33	76	72	70	66	68	72	76	79	75	72	71	75	72
Bismarck, N. Dak.	23	74	74	72	66	64	70	66	65	66	70	74	74	70
Dodge City, Kans.	23	72	71	63	61	61	64	64	64	64	65	68	70	67
Fort Worth, Texas	7	66	61	59	64	64	58	57	62	65	63	63	68	63
Indianapolis, Ind.	38	80	77	72	66	67	67	66	68	70	70	72	78	71
New Orleans, La.	46	79	77	77	76	76	77	79	80	79	77	78	79	78
Parkersburg, W. Va.	27	80	80	74	68	70	74	73	76	78	76	76	80	75

TABLE XV—SUNSHINE (PERCENTAGE OF POSSIBLE)

Stations	Length of Record, yrs.	Jan.	Feb.	Mch.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	An'l
Chattanooga, Tenn.	17	41	45	46	54	62	62	60	60	62	65	54	42	55
Knoxville, Tenn.	16	41	49	51	55	68	63	62	59	62	71	60	44	56
Memphis, Tenn.	15	46	53	57	63	72	72	73	70	72	69	62	43	63
Nashville, Tenn.	19	43	48	52	61	68	69	70	69	70	66	56	40	59
Atlanta, Ga.	22	48	53	54	62	69	69	61	60	65	66	62	47	60
Bismarck, N. Dak.	18	54	59	53	59	59	61	70	66	62	60	50	47	58
Columbia, Mo.	19	54	56	57	62	67	71	73	73	66	67	61	53	63
Dodge City, Kans.	17	64	66	65	68	66	73	76	78	72	74	68	68	70
Indianapolis, Ind.	19	39	48	46	53	58	65	68	65	66	62	53	40	59
New Orleans, La.	26	49	49	57	59	67	61	53	55	61	64	55	45	57
Parkersburg, W. Va.	18	27	23	38	49	55	58	61	58	58	49	35	25	44

Manganese Deposits of Bradley County*

By A. H. Purdue.

The deposit of manganese on White Oak Mountain, Bradley County, has previously been described by Mr. W. A. Nelson.† This deposit occurs in the Fort Payne chert of Lower Carboniferous age.

In October, 1916, a new deposit was opened up a little more than a mile east of Marble Switch on the Southern Railroad, and something like nine miles south of Cleveland. In September, 1917, a second opening was made two miles north of the first one on a farm belonging to Mr. A. B. Hambright.

The manganese is in an area mapped by the late Dr. C. W. Hayes as Tellico sandstone,‡ of Ordovician age. It occurs in a limestone which was not mapped by Dr. Hayes but which lies immediately below the Tellico sandstone and probably is the Holston marble. This limestone is gray, crystalline, fossiliferous, and contains a large per cent of iron. The iron is hematite, and occurs in thin, paper-like sheets most of which are parallel with the laminae, but some are wrapped almost around the fossils and others are in veins that stand at a high angle to the lamination. Also, it is this limestone and the residual soil above it that carry the manganese. The sandstone, limestone, and other rocks beneath them, dip at a high angle south of east. Excellent structure sections are shown by Dr. Hayes.‖ This ore was deposited in solution caverns in the limestone, which, so far as the writer could observe, were along the bedding planes of the limestone. This gives the manganese the appearance of a bedded deposit of the same age as the limestone, and is so considered by those working the deposits. As the writer observed them, the manganese layers vary from a few inches in thickness to as much as fourteen inches. The ore, which is reported to be of very high grade, is found

*This article was dictated by Dr. Purdue on the morning of the operation which resulted in his death, and he therefore had no opportunity to look over the manuscript.

†Res. of Tenn., Vol. I, No. 6, pp. 220-228.

‡U. S. Geol. Surv., Cleveland folio, No. 20.

‖Loc. cit.

both in the caverns above mentioned and in the residual clay, from which bowlders have been taken out that weigh 800 pounds.

Associated with the manganese is iron ore whose color indicates that it is manganiferous; but this and the manganese are never so closely associated as to prevent hand picking.

It seems without question that the immediate source of both the iron and the manganese is the Tellico sandstone, which is described by Dr. Hayes* and others in the East Tennessee folios. This sandstone, which is responsible for the ridge whereon the manganese occurs, breaks down into a deep chocolate-colored to red soil.

A fault, which is mapped by Dr. Hayes, occurs a short distance east of the deposits, but there is no genetic relation between this and the ores.

To the present time, the work has all been done by hand, but at the southernmost area, steam shovels are being installed. It appears that the operators expect to secure about one ton of manganese to each hundred tons of residual material; but this cost of recovery will be reduced by the cavern deposits yet remaining in the limestone.

The belt in which ore may reasonably be expected is perhaps 100 yards wide. In this area it is seven miles long and extends southward into Georgia.

There are other prospects in the vicinity of Hiwassee River, east of Charleston, but unfortunately the writer has not been able to see these. The area in which these deposits occur is mapped by Hayes as the Tellico sandstone, underlain by the Athens shale. Should there be no limestone beneath the Tellico sandstone, as in the area south of Cleveland, the manganese would be expected in largest quantity at the base of the sandstone, and resting on the shale. This area extends northward to a point five miles northeast of Athens and has a total length of more than twenty-five miles, with an average width of the Tellico sandstone area of more than a half mile; but as in the southern area, the belt in which manganese can be expected would be narrow.

There are many other belts of outcropping Tellico sandstone in East Tennessee that are shown in the several folios of that area by the U. S. Geological Survey. In view of the great war demand for manganese at this time, all these areas should be looked into as possible sources of that mineral.

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*Loc. cit.

Barite Deposits of the Sweetwater District, East Tennessee

By C. H. Gordon, University of Tennessee, Knoxville.

INTRODUCTION.

Prior to 1914, the barium industry in the United States was on a precarious footing owing to the fact that European barite could be sold to the eastern manufacturers cheaper than the domestic ore. While large deposits of barite exist in Missouri, Georgia, Tennessee, Kentucky, and Virginia, the high freight rates to the chief markets which are east of the Allegheny Mountains combined with the low market price of the ore as determined by the cheap ores from Europe was a serious handicap to the production of crude barite in this country. The government statistics* for 1916 show almost a complete cessation of imports of crude barite and 42 per cent decrease in the manufactured products over the imports of 1914. The increase in prices which naturally followed removal of foreign competition has given a great impetus to American production, and many mines, idle for years, have taken on renewed activity and new properties have been opened. The year 1915 showed a marked advance in the production of crude barite over that of 1914, but the year 1916 broke all previous records with a total production of 221,952 short tons valued at $1,011,232, an increase of 104 per cent in quantity and 165 per cent in value over the output of 1915. While there was a large increase in output in all the states heretofore producing, the outstanding feature of the report for 1916 is the displacing of Missouri as the leading producer by Georgia and the entry of Colorado and Nevada into the list of producing states. The revival of the industry has been especially marked in Tennessee, where the output for 1916 was 32,416 short tons valued at $123,968, an increase of 220 per cent in quantity and 625 per cent in value over the output of 1914.

To meet the demand for information concerning the Sweetwater deposits in East Tennessee, the writer spent some time in the field

*Mineral Resources of the United States for 1916, Pt. II, pp. 243-254.

during June, 1917, and presents herein the results of the investigation then made.

The following papers comprise most of the important writings pertaining to the Sweetwater district:

Fay, A. H., Barytes in Tennessee, Eng. and Mining Jour., vol. 87, p. 137, 1909.

Grasty, J. S., The Barite Deposits in Tennessee, The Tradesman, May 1, 1917, pp. 34-38.

Hayes, C. W., U. S. Geological Survey, Cleveland Folio, (No. 20), 1895; Kingston Folio (No. 4), 1894.*

Keith, Arthur, U. S. Geological Survey, Loudon Folio (No. 25), 1895.*

Henegar, H. B., Barite Deposits in the Sweetwater District, The Resources of Tennessee, vol. 2, pp. 424-429, Tennessee Geological Survey, 1912.

Herzey, C. S., Tennessee Barytes, Mineral Industry, vol. 10, p. 58, 1901.

Judd, E. K., The Barytes Industry of the South, Eng. and Min. Jour., vol. 83, pp. 751-752, 1907.

Watson, T. L., Fluorite and Barite in Tennessee, Trans. Am. Inst. Min. Eng., vol. 37, p. 890, 1907

Watson, T. L., and Grasty, J. S., Barite of the Appalachian States, Amer. Inst. Min. Eng., Bull. 98, pp. 369-374, Feb. 1915.

Weller, C. A., Barytes Mines of the Commercial Mining and Milling Co., Eng. and Min. Jour., vol. 83, p. 851, 1907.

For information concerning the deposits of barite in the Appalachian region outside of Tennessee, the following, many of which contain references to the Tennessee deposits, may be consulted with profit.

Grasty, J. S., Barite Deposits of Alabama, The Tradesman, July 17, 1913, pp. 35, 36.

Hayes, C. W., and Phalen, W. C., Barite Near Cartersville, Georgia, U. S. Geol. Surv., Bull. 340, pp. 458-462, 1908.

Hill, James M., Mineral Resources of the United States for 1915, Pt. 2, pp. 161-187. 1916.

Fohs, F. J., Barite Deposits of Kentucky, Kentucky Geological Survey, 4th. ser., vol. 1, Pt. 1, pp. 441-588, 1913.

The author takes pleasure in acknowledging the cordial co-operation and assistance received from Mr. H. B. Gilman, Vice President and General Manager of the Duplex Chemical Corporation whose wide acquaintance with the field and unfailing courtesy greatly facilitated the investigation. Among others who contributed services or information, special mention is due Mr. H. J. Moore and Mr. G. R. McMahan and to these we extend our cordial thanks.

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*The government folios describe the geology of the region but make no mention of the barite deposits.

NATURE AND OCCURRENCE OF BARITE.

Physical character—Barite* is a white, opaque to translucent crystalline mineral having a hardness of 2.5 to 3.5, or very nearly that of calcite. Its specific gravity is relatively high, 4.3 to 4.6, and this together with the fact that it does not effervesce when treated with hydrochloric (muriatic) acid readily distinguishes it from calcite, whose specific gravity is 2.71. Barite crystallizes in the rhombic (orthorhombic) system, the crystals being usually the combination of the unit prism and the basal pinacoid, but well formed crystals are rarely found in the Sweetwater area. The mineral occurs usually as aggregates of straight, or slightly curved, cleavable plates, or in granular, fibrous, earthy, stalactitic or nodular masses. The plates, which are commonly united by their broad sides in crested, divergent groups, separate readily when struck with a hammer. The mineral is brittle, breaking with an uneven, or conchoidal fracture and when unaltered has a vitreous pearly luster but it becomes a dull, earthy white as a result of weathering. The color is typically white, varying to light shades of yellow, brown, red or blue. The Sweetwater barite is commonly white or gray, sometimes shading to light brown or pink as a result of iron stain. Before the blowpipe, barite decrepitates readily, fusing at about 3 and coloring the flame yellowish green.

Chemical character.—Barite is the sulphate of barium ($BaSO_4$), and contains when pure 65.7 per cent of baryta, or barium oxide (BaO), and 34.3 per cent sulphur trioxide (SO_3). In nature it practically always includes other elements of which the most common are silica (SiO_2), lime (CaO), magnesia (MgO), and the oxides of aluminium, iron, and manganese. Sometimes strontium is present, the Kentucky deposits† showing from a trace to 11 per cent of this substance. The Sweetwater deposits also contain a small amount of strontium as shown by the accompanying analyses. The strontium is present usually in the form of sulphate and for the most uses the presence of a small amount of this substance is not considered objectionable. Hence determinations of strontium are not commonly made.

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*Known also as Baryte or Barytes, and Heavy Spar, from *barus* meaning "heavy".

†Fohs, F. J., Kentucky Geological Survey, 4th. ser., vol. I, pt. 1, pp. 450, 451.

Associated minerals.—The most common associated minerals are calcite, fluor spar, zinc blends, galena and, less frequently but locally of importance, quartz, strontianite, pyrite, limonite, chalcopyrite, smithsonite, and manganese oxide. The first four minerals mentioned are present in varying amounts in the Sweetwater deposits. Limonite and quartz in the form of chert are the most common minerals associated with the barite. There is a small amount of manganese oxide but strontianite, chalcopyrite, pyrite and smithsonite are of rare occurrence.

Similar species.—Other heavy, light-colored minerals with which barite may be confused are witherite ($BaCO_3$), strontianite ($SrCO_3$), and cerrussite ($PbCO_3$), all of which, however, effervesce with acids. From quartz it is distinguished by its greater weight and lesser hardness; also by its platy or cleavable structure, quartz being without cleavage.

The only other barium mineral of importance is witherite ($BaCO_3$), which carries when pure 77.7 per cent of baryta (BaO), and 22.3 per cent of carbon dioxide. It occurs commonly in globular and botryoidal forms whose structure may be columnar or granular. When crystallized it is usually in hexagonal prisms whose faces are rough and longitudinally striated. Like calcite it is readily soluble in hydrochloric acid with effervescence but is easily distinguished from that mineral by its greater weight and hardness, and from barite by its solubility. Its chief occurrence is as a gangue mineral in metaliferous deposits. The only known commercial deposit of *witherite* in the world is located at Fourstones, Northumberland County, England. The mineral is not known to occur in Tennessee. If present here observers should be able to detect it by means of the above description.

Occurrence.—Barite is a common mineral and has a wide range in geologic age and in geographic distribution. It may be found in many kinds of rocks, igneous, sedimentary and metamorphic. It is a common gangue mineral in metallic ore veins but as such is not of commercial value. According to Ries* it has in nearly all cases been formed by deposition from aqueous solutions and is not found as an original constituent of igneous rocks, nor in contact metamorphic zones or pegmatite veins. Commercially economic deposits of barite may comprise the following:

*Ries, Heinrich, Economic Geology (1916), p. 309.

I. Veins.

1. Fissure or fault breccia veins of which those of Kentucky are good examples. In these the mineral occurs in brecciated fault zones chiefly as a vein filling from solutions, but replacement deposits and simple veins are known.

2. Bed veins or shattered zones in limestone in which the barite occurs as a replacement, or cement filling the interstices in the breccia.

II. Irregular bodies formed by:

1. The replacement of beds of limestone or pyrite, or

2. The filling of solution caves or breccias.

III. Residual deposits formed by the weathering of any of the above.

In such deposits the barite occurs in lumps and masses in the residual clays derived from the weathering of the limestones containing barite ore bodies.

The Tennessee deposits fall under I.2, and III in the above classification.

BARITE DEPOSITS OF THE SWEETWATER DISTRICT.

Physiography—The Sweetwater area lies near the middle of that part of the Great or Appalachian Valley included within the limits of the State of Tennessee. Sweetwater, a station of the Southern Railroad 42 miles southwest of Knoxville is near the center of the district. Topographically the area presents the ridge and valley type characteristic of the Great Valley in this region. The ridges formed by the more resistant strata alternate with valleys dissolved or worn out of the intervening softer strata, and all trend from northeast to southwest in conformity with the main structural features of the valley. With the exception of a small area in the southwest corner, the drainage of the district is effected by a parallel system of northeast-ward-flowing streams including the Fork, Sweetwater, Pond and Stockton creeks all of which empty into the Tennessee River except the Fork, which empties into the Little Tennessee several miles above its mouth. The valley of the Sweetwater is one of the most important and charming valleys in the State. The streams flow throughout the year, being supplied by springs which are abundant and many of them large. The water supply of Sweetwater comes from two large springs at the south edge of the town.

STRATIGRAPHY

With the exception of a small area in the northwestern part of the district, the rocks belong to the Cambrian and Ordovician systems, the outcropping formations occurring in belts extending from northeast to southwest. The Cambrian is represented by eight narrow bands of shales and sandstones. East of Sweetwater, the shales there called the Nolichucky shales predominate in the belts. West and northwest the shales, there called the Conasauga, are overlaid by siliceous beds called the Rome sandstones. Alternating with the belts of Cambrian formations are wider bands of limestones and dolomite most of which belong to the Ordovician, the next later system to the Cambrian. Chief among these is the great Knox dolomite formation which underlies the larger part of the district and in which the deposits of barite occur. The Knox is a massively bedded dolomitic limestone containing in places a large amount of chert, locally called "flint". The chert occurs in nodules and masses in the strata sometimes in such amount as to almost constitute beds. By reason of its greater resistance to weathering influences the beds containing the chert yield more slowly to wasting agencies and these stand out in more or less prominent ridges. In such areas the soils are stony and poor owing to the large amount of chert left by the decay of the overlying beds, often in such amounts as to make cultivation almost impossible.

Accompanying the Knox are higher formations of shales (Athens), limestones (Stones River), and ferruginous sandstones (Tellico) of the same (Ordovician) age. The red sandy Tellico formation occurs in two narrow bands one on the east side of Fork Creek and the other extending northeast from Sweetwater. This formation thins rapidly from east to west in the valley, its western limit being originally not far west of the town of Sweetwater. Owing to its greater resistance to wasting agencies the Tellico forms ridges marked by rounded knobs, the so-called "red knobs" of Eastern Tennessee. The cementing constituent of the Tellico beds is lime carbonate by the leaching of which the iron contained in the formation is concentrated, forming in places workable deposits of iron ore. Such deposits have been worked to some extent about two miles northeast of Sweetwater.

In the northwestern part of the district is a small area* covered by formations of later age than the Ordovician. These comprise the Rockwood (Clinton) iron ore formation (Silurian), the Chattanooga shale (Devonian) and the Fort Payne chert (Mississippian). In this area are located the Chamberlain iron ore mines which work deposits of the Rockwood ores.

GEOLOGICAL STRUCTURE

A conspicuous feature of the geology of the valley region is the occurrence of the formations in parallel belts extending from northeast to southwest. As a rule the strata dip rather steeply to the southeast but in some belts the dip is to the northwest. The widths of the outcrops of the sandstone, shale and limestone formations are from one to six miles. The repetition of similar formations is due to folding and faulting on a large scale as a result of compressive forces which bent the strata into folds which by the continuance of the thrust broke in some instances along their northwest side permitting an overthrust of the strata toward the northwest. The upper parts of the earth blocks thus formed were then planed off by erosion leaving the different formations exposed in parallel belts. These movements appear to have reached their culmination soon after the close of the Carboniferous period. Seven great faults occur within the boundaries of the district as mapped, in addition to which there are many minor breaks and slips. Beginning at the southeast side the first fault is the Bays Mountain Fault† which follows the south side of the ridge of "red knobs" about half a mile west of Hiwassee College. Next bounding the Fork Creek dolomite belt on the west is the Knoxville Fault† which is about half a mile southeast of Sweetwater. Next following the northwest side of Black Oak ridge is the Clinch Mountain Fault which extends entirely across the State and has a known length of approximately four hundred miles. This fault is paralleled on the northwest by the Beaver Valley Fault† which is succeeded by the Maynardville Fault† seen at Pattie Gap. Next in order is the Wallen Valley Fault† and lastly the Kingston

*The area mapped includes portions of the Loudon and Kingston quadrangles, the geology of which is given in folios published by the United States Geological Survey.

†Name given by the author in Bulletin No. —, Marbles of East Tennessee, Tennessee Geological Survey, (in Ms.).

Fault* in the extreme northwest corner of the area mapped. The dip of the beds in general is from 10 to 40 degrees to the southeast, more commonly 20 to 30 degrees. In some cases, especially in the immediate vicinity of a fault, the dip may approach the vertical.

CHARACTER OF THE ORE DEPOSITS

Geological occurrence.—The barite of the Sweetwater district occurs in two forms of deposits, viz., as bedded veins or shattered zones in the Knox dolomite (type No. 2 of Class I), and as lumps and masses in the overlying residual clays derived from the decay of the dolomite (Class III). The last named deposits only are of commercial importance.

Three separate veins or belts are recognized though these may be one and the same repeated by faulting; they are the Howard vein, the Garrison vein and the Culveyhouse vein so-named from the well known mines located upon them:

The Howard vein is in the Fork Creek valley about three miles southeast of Sweetwater. It parallels that stream along the northwest side throughout most of its known extent. The Garrison vein lies about four miles northwest of Sweetwater following Pond Creek Valley, and the Culveyhouse is about six miles northwest of the town, a part of it lying within Stockton Valley.

The location of these veins is shown on the accompanying map. All three occur in the Knox dolomite areas and appear to occur at very nearly the same horizon in the formation, viz., at about one-third its thickness below the top of the formation, or about the horizon designated by Ulrich as the top of the Copper Ridge Chert. If, as this author asserts†, there is a stratigraphic break at this horizon this fact may have a bearing on the origin of the ore accumulations. While no conclusive evidence establishing this position was obtained by the writer, the impression gained was in favor of the conclusion advanced by Mr. Ulrich.

A few small deposits appear to lie outside the limits of the veins mentioned, but they are apparently local and do not include any of importance.

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*Name given by the author in Bulletin No. —, Marbles of East Tennessee, Tennessee Geological Survey, (in Ms.).

†Ulrich, E. O., Revision of the Paleozoic Systems, Bull. Geol. Soc. of America, vol. 22, 1911, p. 638.

Original source of the barium.—As stated by Dr. Ries*, barite "is in nearly all cases formed by deposition from aqueous solutions". Descending waters carrying barium sulphate in solution following the easy channels provided by the cavernous, brecciated zone having deposited the sulphate upon the walls more or less completely filling the spaces, and cementing the mass together. The source of the barium was evidently in the dolomite and associated limestones, great thicknesses of which have in the course of time been removed by solution. To ascertain if the asso[illegible] may have furnished the barium, analyses were made with the following results:

Analyses of the Knox dolomite

	SiO_2	Al-Fe	CaO	MgO	$BaSO_4$	BaO	S	So_3
1.	4.00	1.02	29.48	19.47	...	.04	tr.	...
2.	8.64	1.22	28.96	17.61	.03	.09	.04	.12
3.	11.34	.84	45.00	2.59	.08	.05	.13	.10

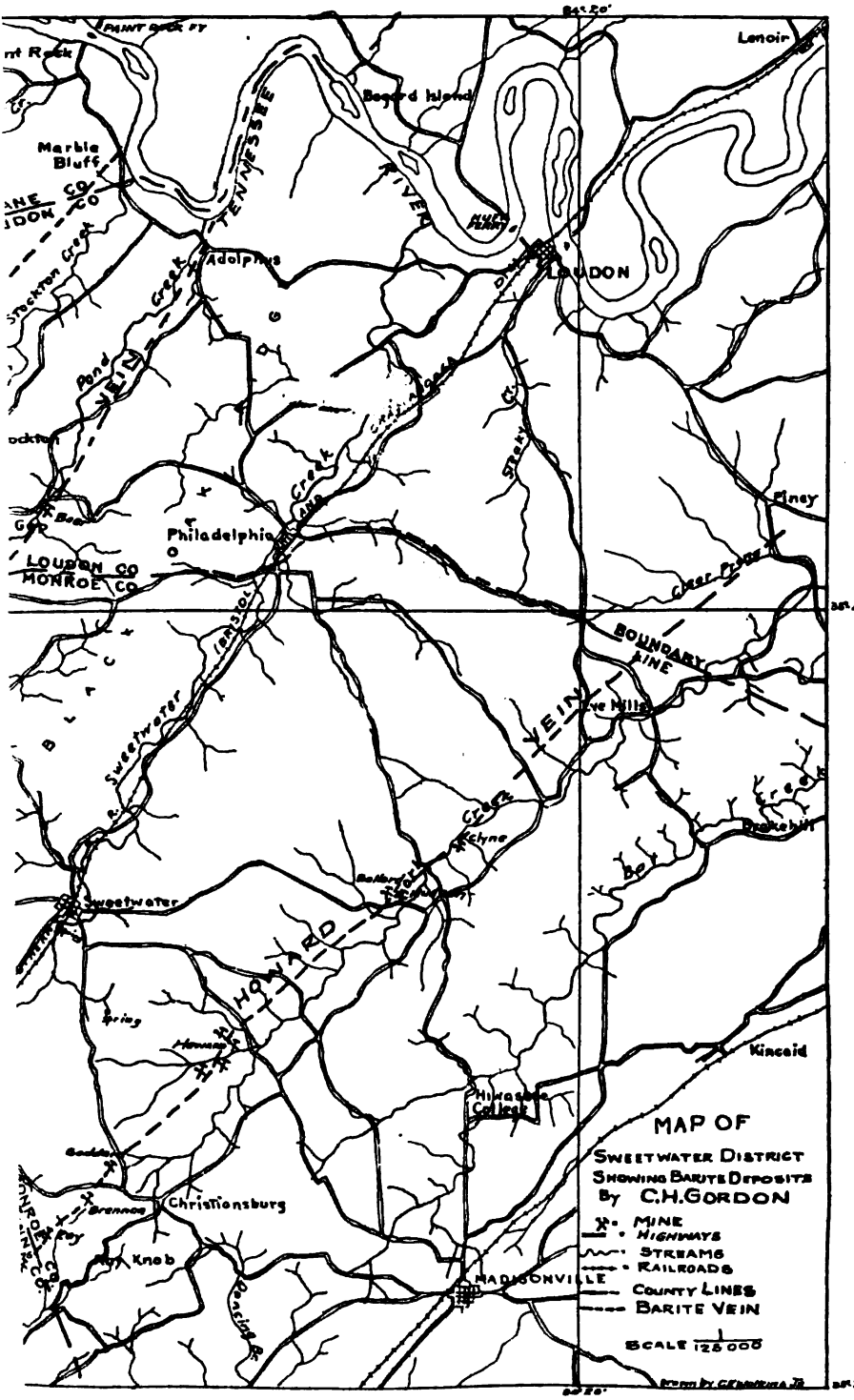
PAUL C. BOWERS, Analyst.

1. From ledge of dolomite just below the barite deposit in the Clyne mine.
2. Outcrop of dolomite one-half mile southeast of the Clyne mine.
3. Pinnacle or "horse" in the Kyker mine.

These analyses indicate the presence of barium in appreciable quantities both as sulphate and oxide and confirm the view that these beds have by their dissolution furnished the material for the filling of the veins. Number 3 is a limestone intercalated in the dolomite series. A sprinkling of small grains of quartz in this rock accounts for the high content of silica shown in the analysis.

Nature of the deposits.—In their original form the ores were deposited by solutions circulating within a zone of brecciation in the Knox dolomite, thus cementing the broken rock into a solid mass. Indications of deposition in irregular spaces is seen in the banded and crested structure of the ore while in some cases deposition appears to have ceased before the cavity was completely filled, leaving vacant spaces or "vugs" lined with projecting cystals of barite. In a few mines, notably the Howard, Johnson, Ballard and Minton, the underlying dolomite has been exposed showing the unaltered vein breccia composed of fragments of dolomite cemented together by barite and in places fluorite. Above the solid rock the barite is often found in large cavernous masses the spaces filled with clay repre-

*Op. Cit.



Sweetwater District.

senting the residuum from the limestones which originally filled the space. In some instances the limestone fragments had not undergone complete decay. (Fig. 5).

The unaltered ore is crystalline massive, gray or grayish white sometimes stained pink or brown by iron oxide, and with vitreous luster. Under the influence of the weather the mineral assumes a

Fig. 2—a. Cavernous barite. When taken from the mine the spaces are filled with clay resulting from the decay of the dolomite fragments which originally occupied them.
b. Original vein material. The white is barite, the gray is dolomite.
c. Cavernous fluorite. The spaces are due to the decay of the fragments of dolomite that originally occupied them, as in the case of a.

dull lustreless white appearance and ultimately crumbles to a white powder. Hence the surficial portions of the residual deposits are likely to be reduced to a fragmental condition known as "gravel" ore. No effort has been made to work the unaltered vein nor is it likely that efforts to do so will prove successful owing to the greater cost of mining and the difficulty of separating the ore from the limestone.

All of the output of barite from the Sweetwater district, as stated above, comes from the residual clay deposits resulting from the weathering of the inclosing dolomite. The barite being less soluble than the dolomite resists longer the action of the weather and remains distributed as lumps and masses in the clays.

Workable deposits appear only at intervals along the outcrop of the vein, barite showing only in traces perhaps, in the intervening areas. In places the surface appears to have been covered by a deposit of alluvial clay and hence more exhaustive prospecting may reveal the presence of barite in vein localities where no ore now shows at the surface. However, the conditions for ore accumulation (brecciation, etc.) are likely to be the same throughout the extent of the vein and hence localization of deposits is likely to be the rule rather than the exception. The ore will naturally be most abundant in areas where brecciation of the dolomite, and consequent vein filling, was most pronounced and it is these areas that contain workable bodies of ore.

Chert in varying amounts is present in all the deposits, but it occurs in greater amount in the western or Garrison and Culveyhouse veins. The chert was originally inclosed in the dolomite and being highly resistant to weathering it remains commingled with the barite in the residual clays. It may occur inclosed in barite or in separate masses in the clay.

The ore belt at the surface is usually from 100 to 300 feet wide. The width of the shattered zone or vein proper is probably less, but as no workings have fully exposed the vein its width and dip can not be authoritatively given. Available data seem to corroborate the view held by operators that the vein dips to the southeast in conformity with the dip of the rocks. With disintegration of the beds there followed naturally not only a concentration of ore at lower levels but a spreading of the ore as it was lowered and hence the greater width of the surface outcrop of the deposits as compared with the original vein. (Fig. 3).

Overlying the barite deposits in many places is a variable thickness up to six or eight feet of alluvial red clays of later origin than the residual clays beneath. The removal of this by erosion deposit has exposed the barite where it now appears at the surface. At the Ballard mine these alluvial clays containing rounded pebbles indicative of their origin appear resting upon the uneven eroded surface of the residual baritiferous clays.

The ore is not uniformly distributed but occurs in pockets separated by barren areas. In some of the mines, notably the Ballard, the deposit is intersected longitudinally by a cherty reef or ledge called the "midrib", which owing to its greater resistance to solu-

tion has not suffered so much from decay as the less cherty beds by which it is flanked on either side.

The effect of weathering on the ore is to cause it to break up into small pieces, the so-called "pebble" or "gravel" ore. In places the surficial portion of the deposit is made up in large part of this "gravel" ore. Under former methods of mining most of this was cast aside but with the introduction of log washers much of it can be saved.

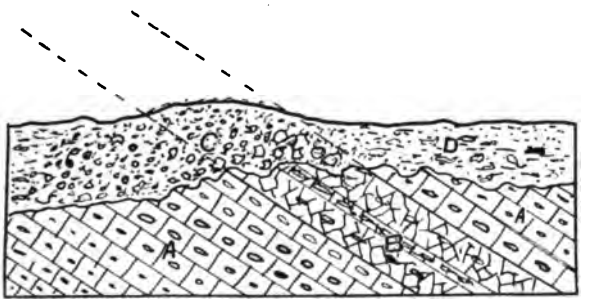


Fig. 3. Ideal section showing relations of residual deposits to the original vein. a. Knox dolomite. b. Brecciated zone with a more resistant middle stratum, the socalled "midrib". c. Residual clays with barite and chert resulting from the decay of the vein breccia. d. Residual clay and chert.

Associated minerals.—Fluorspar is a frequent occurrence in the mines. It is especially abundant at the Howard, Ballard and Minton mines. Usually it is confined to certain parts of the vein while other parts are entirely free from it. The mineral occurs both as a filling on the limestone breccia similar to the barite, and in crystals in cavities. Cavernous masses (Fig. 2c) left on the decay of the included limestone fragments are common in all the fluorspar areas. Sometimes the fluorspar occurs alone but usually barite and fluorspar are more or less intimately intermingled. Where they occur together the barite is inclosed in the fluorite indicating it to be of earlier formation.

While it appears that a considerable amount of fluorspar occurs in some of the deposits, no reliable estimate can be given as to the quantity, since it is the practice of the miners to abandon areas in which fluorspar makes its appearance. It is believed that some of the deposits of fluorspar may be workable but the most serious difficulty to be surmounted will be the separation of the mineral from

the barite, though this may be effected by jigging as its specific gravity (3.1) is less than that of barite (4.5).

Chert or impure flint is present in greater or less amount in all the deposits. It increases westward, being especially prominent in the western veins. The unaltered chert is of a dark, almost black color but on weathering it becomes gray or white. Much of the chert is porous from the leaching out of calcium carbonate. This mineral is highly resistant to weathering but after long exposure it crumbles to a white powder. Deposits of it are sometimes worked for much the same uses as tripoli, viz., polishing powders, soap filling and boiler and steampipe covering. A deposit of this kind near Cleveland, Tennessee produces what is known commercially as "silex". At first glance the white chert may be mistaken for barite; it is readily distinguished from that mineral by its lighter weight and greater hardness.

Iron oxide in the form of brown iron ore or limonite occurs in varying amount. In some deposits it is present in considerable quantity. It often forms a thin layer, one-sixteenth to one-eighth inch thick around the barite, but may occur also inclosed within it. It is confined to the weathered deposits and appears to have been deposited by solutions following openings caused by the initial decay of the limestones. It is more abundant in some mines, and in different parts of the same mine, than it is in others. It is especially prominent in the Howard vein due possibly to the presence in this area of the Tellico beds whose decay may have furnished the iron to the waters circulating through the beds below.

Sphalerite or zinc sulphide occurs in small amount in places, as does also galena, the sulphide of lead. Anglesite, the sulphate of lead, occurs in the Culveyhouse mine in which instance it results from the alteration of galena.

Calcite, or lime carbonate, in masses showing the characteristic rhombic cleavage is occasionally found.

Manganese oxide is present in small amount but celestite ($Sr.SO_4$) and chalcopyrite, minerals often found associated with barite have not been observed. Analyses of the barite, however, indicate the presence of strontium in small amount as shown below in Kentucky samples:

Analyses of the Sweetwater barite

	SiO_2	Al-Fe	CaO	MgO	$BaSO_4$	Sr.	SrO
Average sample from Durex works.....	.32	.38	.24	.04	97.88	...	...

PAUL C. BOWERS, Analyst.

For comparison the following analyses of the Kentucky barite is given:

*Analyses of barite from Kentucky**

Substances	3530	3532	3533	3534	3536	3538
Barium sulphate	77.44	91.76	98.54	91.06	83.67	98.40
Strontium sulphate	16.31	6.90	tr.	4.38	12.25	0.37
Calcium sulphate	2.47	0.53	0.00	0.00	0.00	0.00
Calcium fluoride	5.03	1.06	0.00	2.91	0.28	0.00
Calcium carbonate	0.00	0.00	0.00	1.07	0.10	0.00
Zinc carbonate	tr.	0.00	0.00	0.00	1.89	0.00
Spec. gravity	4.228	4.456	4.444	4.291	4.428	4.523

Galena and the other metallic sulphides, sphalerite, Chalcopyrite and pyrite, are harmful, as they discolor the ground product. Unless present in large amount the quartz, calcite and fluorite may be eliminated by proper treatment. In some places, however, the fluorite occurs in such amount as to make necessary the abandonment of these areas. Small amounts of iron oxide may be removed by treating the ground product with sulphuric acid. In some of the mines where iron oxide is present in considerable quantity, most of it is removed by cobbing. Manganese is difficult to remove, but this substance is not present in very large amount in the Sweetwater district.

DESCRIPTION OF THE DEPOSITS.

Introduction.—As previously stated (page 55) the Sweetwater deposits occur in three veins which may be designated as the Howard vein, the Garrison vein and the Culveyhouse vein. They are all located in the Knox dolomite and occupy an horizon about one-third of its thickness below the top of that formation corresponding approximately with the top of the Copper Ridge chert division as defined by Ulrich.

HOWARD VEIN

This vein is located about 4 miles southeast of Sweetwater and upon it deposits of barite have been located at intervals from a point 6 miles northeast of Sweetwater to Athens a distance of 17 miles. This vein was the first to be worked, the Howard mine supplying the first ore shipped from this district. It is estimated that nearly 100,000 tons of barite have been taken from this mine.

*Fohs, F. J., Kentucky Geological Survey, Ser. IV, vol. 2, pt. 1, pp: 450-451, 1913.

Clyne mine.—This is the most northerly opening made on the Howard vein. It is located on the east bank of Fork Creek about six miles northeast of Sweetwater. The ore occurs in residual clay resting upon the uneven surface of the Knox dolomite, pinnacles of which rise above the floor of the mine. The decay of the dolomite or limestone has proceeded very unevenly as shown by a test hole located within a few feet of one of the pinnacles which penetrated 45 feet of barite-bearing clay without reaching the bottom. The pinnacles showing through the clay in the mine consist of shattered dolomite cemented together with barite. At this place the strata appear to be nearly horizontal but one-fourth of a mile east the dip is about 12 degrees south 45 degrees east. The thickness of the ore-bearing clay here ranges from one to over 45 feet. This mine was worked to a limited extent at one time but has been idle for a number of years. Work has been resumed recently by a company headed by Mr. J. F. Doherty and Mr. G. R. McMahan of Sweetwater. At the time of our visit development work was in progress.

Three hundred yards northeast of the present workings on the opposite side of the creek the surface is strewn with pieces of barite, but no work has been done at this point.

Ballard-Hudson mines.—About one and one-fourth miles southwest of the Clyne, on the west side of the creek and north of the road leading to Sweetwater are the Ballard and Hudson mines. The Hudson which lies next to the creek has produced about 2,000 tons of ore but it is now idle.

The Ballard adjoins the Hudson on the west. The opening is near the top of the slope about sixty feet above the creek bottom. The workings cover a space about 300 feet wide and 1000 feet long. Extending longitudinally through the middle of the mine is a reef or ledge of undecomposed or partially decomposed vein rock which the miners call the "midrib". This reef is about 75 feet wide and consists of brecciated cherty limestone containing barite, fluorspar and iron oxide. This "midrib" is flanked on both sides by ore-bearing clays which have worked to a depth of 50 to 60 feet and testing shows them to extend 10 to 20 feet deeper. At one place the "midrib" has been decomposed nearly to the bottom of the mine opening a passageway from one pit to the other. Fluorspar is prominent in the "midrib" but there is none present in the areas on either side.

Alluvial deposits of variable thickness rest upon the eroded surface of the residual ore-bearing clays.

A washer has been installed here and is operated with water pumped from the creek. The ore is extracted with pick and shovel and transported by wheelbarrow to the washer. The quantity of ore in sight here is large but there is a large amount of waste owing to the presence of iron oxide. The mine is operated under lease by Moore and Evans with a daily output of about 100 tons. To date this mine is reported to have yielded about 20,000 tons of ore.

Howard mine.—This mine is located about three and one-half miles southwest of the Ballard mine in a small valley tributary to

Fig. 4. The Howard mine. Worked by pick and shovel.

Fork Creek on the north side. The Howard was the first mine to be operated in this district. The old workings, now mostly filled in, are located on the south side of the branch. A large amount of ore was taken from this pit which is said to have reached the limestone below. The present workings are on the north side of the branch following the strike of the vein. Two pits are now being worked, one about 200 yards northeast of the other. The width of the vein as shown by outcroppings of ore in the bed of the dry weather branch which forms nearly a right angle with the vein is about 600 feet. The two openings now working cover an area of about 4500 square feet and extend to a depth of 30 to 40 feet. A shaft 18 feet deep

in the more northerly pit with good ore to the bottom fails to reach the limestone. Some ore has been removed from some shallow workings still farther northeast. The ore occurs in pockets alternating with lean and barren areas.

A large mass of fluorspar was struck in the pit nearest the branch, but this mineral has not been observed in the other workings.

Mining is done by pick and shovel the ore being handpicked and hauled to Sweetwater by wagon. The mine is operated by lease by the Durex Chemical Corporation of Sweetwater and Baltimore, Md. It is said to have produced about 50,000 tons of ore to date.

About 400 yards south 70 degrees west and a like distance north of the Howard mine are other small pits which have been located apparently on a parallel vein. These deposits seem to be limited and are not being worked at the present time.

Goddard mines.—Two to two and one-half miles southwest of the Howard mine openings have been made on the Goddard property, one on the east, the other on the west of the Sweetwater-Madisonville road. No work is being done on this property at the present time.

Brennan mine.—Three-fourths of a mile southwest of the Goddard mines on the Brennan property is another idle mine. An opening 100 by 300 feet and fifteen feet deep has been made from which about 2000 tons of ore have been extracted. The ore shows up well in the sides of the pit but it is mostly "gravel" ore which will require washing for which no water is available. It is probable that coarser ore will be found at depth. The outcroppings cover an area of about 300 feet by 1000 feet.

Roy mine.—Adjoining the Brennan on the southwest is the Roy property owned by the two Roy brothers. The mine comprises several openings on the south half of the estate. This mine illustrates well the common method of mining in this district known as "hogging", that is, working only the richer leads and shifting in a haphazard way from place to place to often leaving the dumps on ground that may be more productive than that which is being worked. The first and largest pit which is located at the northeast side of the property is about 100 feet wide by 300 long and 70 feet deep. It is now filled with water to a depth of 30 feet, a supply sufficient to operate a log washer if properly conserved. A small gasoline engine has been installed to haul the clay out of the mine. This mine is said to have

produced about 10,000 tons of ore. It is operated on lease by J. F. Doherty and often goes by the name of the Doherty mine.

Stephens prospect.—Deposits are reported to occur on this vein as far southwest as Athens. There is said to be a good showing of ore on the Stephens farm one-half mile southwest of the Roy mine. Barite also appears in the bed of a small branch at Athens.

THE GARRISON VEIN.

This vein lies about 4 miles northwest of Sweetwater in a belt of the Knox dolomite which is bounded on the southeast by the Clinch Mountain fault and on the northwest by the Beaver Valley fault, each of which brings to view a narrow band of Cambrian sandstones and shales. Seven ore bodies have been opened on this vein within a distance of about ten miles. Of these the Barr prospect nearly due west of Philadelphia, the next station on the Southern Railroad north of Sweetwater, is the most northerly outcropping of ore. No work of importance has been done on this prospect.

In all about 25,000 tons of ore have been taken from the Garrison vein.

Lee-Forkner mine.—The Lee-Forkner is the most northerly mine on this vein. It is about 5 miles northwest of Sweetwater. The Forkner property lies on the north side of the road and the Lee on the south side. Operations have been confined to the Lee property where a small opening has been made in the side of the hill from which about 2,000 tons of ore have been removed. The ore in sight begins at the grass roots and consists chiefly of bright crystalline gravel ore. There is apparently a good body of ore remaining in this mine, though no work is being done here at present. This mine belongs to the Durex Chemical Corporation. A washer used in cleaning ores from this and the Culveyhouse and Pfiffer mines was operated here by the W. D. Gilman Company, the predecessors of the Durex Chemical Corporation. An ample supply of water is available from the creek which adjoins the property on the west.

Richardson mine.—The Richardson mine, also owned by the Durex Chemical Corporation, lies about 4 miles southwest of the Lee-Forkner property on the north side of the Sweetwater-Ten Mile road. The "gravel ore" shows well at the hill slope and in the workings which have been extended into the hillside. The ore is im-

bedded in a red clay interspersed with patches of mottled gray and white clays. Chert is not especially abundant.

An opening covering 2,000 square yards and 20 feet deep has been made in the side of the hill from which approximately 3000 tons of ore have been extracted. The surface outcroppings indicate the presence of a large body of ore on this property. As it is predominantly of the "gravel" type its recovery necessitates the use of more advanced methods of mining than formerly prevailed in this district. A log washer has been installed, water for which is available in the small creek at the side of the road, and mining is done with a steam shovel.

Fig. 5. The Richardson mine. Worked by steam shovel. The white spots in the bank at the left of the shovel are in part barite and in part chert.

Anderson mine.—This mine, now idle, is located in a field about three-fourths of a mile southwest of the Richardson mine. About 1000 tons of barite have been taken from a small opening now partly filled with water. The ore, which is mostly of the pebbly variety, contain a rather large proportion of iron, judging from the heap of rejected ore.

Webb mine.—The Webb mine, also idle, is located in the woods about one and one-half miles southwest of the Anderson mine. The workings cover an area 75 by 100 feet and are fifteen feet deep. From this opening about 2000 tons of ore have been removed. Indications

point to the existence of a considerable body of ore on this property, but as it contains much iron and chert a separation plant will be needed for successful operation and water is wanting.

Ore outcrops in a low flat area midway between the Anderson and Webb mines in what is known as the McManus prospect. This locality was not visited by the writer. No development of importance has been made on this property according to report.

Garrison mine.—On the crest of a low hill three-fourths of a mile southwest of the Webb mine is the Garrison mine. The openings here cover an area of about 1000 square yards. The width of the

Fig. 6. The Garrison mine. Worked by pick and shovel. Log washers are in use at this mine for separating the barite from the attached clay.

ore belt is approximately 600 feet separated longitudinally, as at the Ballard, by a "midrib" of hard barren, cherty material. At present mining is confined to the strip along the east side of the "midrib" or reef. The ore is of good quality and fairly free from iron. A small amount of fluorspar is met with in this mine.

Two log washers have been installed, water for which is pumped from a small spring creek 200 yards away. To conserve the limited supply the waste water is caught in a sump and used over again. The ore is mined with pick and shovel and wheeled to the washers in wheelbarrows.

This mine is operated under a lease by Moore and Evans. It has yielded to date about 15,000 tons of ore.

Wattenbarger mine.—About one and one-half miles southwest of the Garrison is the Wattenbarger mine. The principal opening is on the north slope of the hill from which about 2,000 tons of ore have been removed. The mine has been idle for several years but it was recently acquired by the Krebbs Pigment and Chemical Company of Newport, Delaware. Work is now in progress in removing the overburden preparatory to ore extraction. The top of the hill has been dug over more or less but the chief work done was on the northern hill slope. Pinnacles of limestone (dolomite) seamed with barite and calcite appear in an excavation on the east side. The limestone has a dip of 17 degrees south, 30 degrees east. This mine was formerly known as the Thompson mine. It was operated for some time by John T. Williams, the ore being hauled by wagon to Reagan station on the Southern Railroad for shipment.

CULVEYHOUSE VEIN

The third or Culveyhouse vein occurs in the stratigraphic block lying next west of that in which the Garrison is found. This block is bounded on the east by the Beaver Valley fault and on the west by the Maynardville fault. This vein occupies approximately the same horizon in the Knox dolomite as the other veins. An abundance of chert characterizes some of the beds of the dolomite in this area and these, owing to their resistance to erosion, form a rather prominent ridge which northward is known as Copper Ridge.

Johnson mine.—The most northerly deposit noted on this vein is on the Johnson property five and one-half miles northeast of Philadelphia. This mine is located on a mild slope on the west side of Stockton Creek valley. The ore occurs in residual clay in two troughs separated by a reef of more resistant cherty limestone which is notched and pinnacled as a result of differential weathering. The workings cover an area measuring about 75 feet by 150 feet and are fifteen feet deep. A shaft put down alongside the "midrib" to a depth of 45 feet is said to have been all in clay containing good ore. The limestone pinnacles showing in the mine represent the shattered portion of the formation recemented by barite. (b Fig. 2).

The ore is highly crystalline and contains but little iron. Sphalerite, or the sulphide of zinc, occurs in places along with the barite in the original vein matter.

The limestone outcrops at the surface 50 yards northeast of the working showing the ore body to be limited in that direction. Two hundred feet west of the present pits ore crops at the surface but little indications of ore appear in the intervening area.

This mine was recently opened by J. F. Doherty and associates, the ore being hauled to Philadelphia for shipment.

Minton-Thompson mines.—These mines are located on the same vein and about a mile southwest of the Johnson property. They are located on opposite slopes of a narrow valley, the Minton on the east and the Thompson on the west. Several pits have been opened on the Minton property from which about 1000 tons of ore have been taken. The openings on the Thompson are less extensive, 500 tons of ore being credited to this mine. A considerable amount of ore is now on the ground at the Thompson mine awaiting shipment. There is a good showing of ore at the surface and in the faces of the pits in both of these properties. Ledges of limestone and cavernous vein rock show in the lower part of the slopes on both sides. Large cavernous masses of fluorspar and barite appear in the old working on the Minton and a large amount of this material and the original vein breccia appears in the dump. Where weathering has been effective the limestone has been reduced to clay while the more resistant barite or fluorspar remains as a cavernous mass or honeycomb of ore.

Fluorspar is prominent in this mine but the exposures are not such as to justify a definite statement as to its commercial value.

From a longitudinal cut at the top of the hill at the Thompson mine good ore is now being mined, but its shipment must await the convenience of the farmers who furnish teams for hauling the ore to market. Shipment is retarded frequently also by bad roads.

The size of the deposit in this locality is approximately 300 feet wide by 1000 feet long. Both of these properties have been acquired by the Durex Chemical Corporation who also control the only others on this vein toward the southwest now in operation, viz., the Culveyhouse and the Jones-Small mines. Mining has been entirely with pick and shovel. Conditions here would seem to warrant the installation of a log washer, water for which is available from the spring-fed creek adjoining.

Culveyhouse mine.—The Culveyhouse mine is located about one and a half miles southwest of the Minton-Thompson mines. Ore out-

crops in a number of places in the intervening area, the prospects being known as the Thompson (No. 2), Hilton, Bettis and Campbell. A small amount of ore has been taken from some of these, but no extensive work has been done on them.

One of the leading mines on this vein is the Culveyhouse from which about 20,000 tons of ore have been extracted. It occupies a low flat hill top covering an area 200 feet wide by 1000 feet long, the pits being about fifteen feet in depth. No limestone shows in the mine. Operations have been conducted with pick and shovel in a desultory way for about thirteen years. A large amount of ore now lies piled up awaiting favorable road and labor conditions for shipment.

Adjoining the Culveyhouse on the south is the Cox property on which as yet little work has been done.

Pfiffer mine.—About a mile southwest of the Culveyhouse is the Pfiffer mine extensively worked at one time but now idle. The excavation is about sixty feet deep and from it there have been removed 20,000 tons of ore. No limestone shows in the workings but the dolomite outcrops in a branch at a slightly lower horizon one-fourth of a mile west of the mine. At this point the strata dip 20 degrees south, 45 degrees east.

The Brown and Sharp properties adjoin the Pfiffer but no work is being done there at the present time. We are informed that about 5,000 tons of ore have been taken from each of these mines.

Jones-Small mines.—About 5½ miles southwest of the Pfiffer mine are the Jones-Small mines. Ore outcrops in places in the intervening area but the only openings of importance are the Pryor and Gilman mines adjoining the Jones-Small all of which belong to the Durex Chemical Corporation.

The Jones-Small mines are about seven miles west of Sweetwater and about one-half mile north of the Sweetwater-Ten Mile road. The two openings lie on the opposite sides of a shallow ravine, the chief workings being on the Jones property. A log washer has been installed and the ore is extracted from the pit by a steam shovel. Water for the washer is pumped from Big Suee Creek one-half mile away. The excavations cover approximately 200 square yards and in places reach a depth of twenty feet, all in clay. About 25,000 tons of ore have been recovered from these mines.

Kyker mine.—On the south side of the Ten Mile road, one-half mile southwest of the Jones-Small mines is the Kyker mine. The excavations here cover an area approximately 200 feet wide by 600 feet long and vary in depth from fifteen to twenty-five feet. Chert is relatively abundant and pinnacles of limestone are exposed in the deeper workings. The limestone outcrops near the road but little below the level of the bottom of the mine. One of the ledges outcropping in the mine is a dove-colored limestone containing small grains of quartz and little magnesia. This mine has produced about 5000 tons of ore but has not been worked for some years.

Shelton mine.—The Shelton mine is located on the Culveyhouse vein on the north side of the Hiwassee River four miles west of Charleston. A small opening in the southward facing slope has yielded a considerable amount of ore which lies on the dump, no shipments having been made from this mine recently. The ore body lies close to the fault which bounds the stratigraphic block on the southeast, bringing to sight the Cambrian sandstones and shales about 100 yards east of the mine. Barite in abundance appears at the surface above the mine and in the adjoining field owned by T. Bradford. This mine is controlled by lease by the Gilman Paint and Varnish Company of Chattanooga, Tennessee.

From the Kyker to the Shelton, a distance of twenty-five miles, the Culveyhouse vein has not been fully explored. Deposits of barite are reported to occur near the south end of this area and it is probable that investigation will reveal the presence of a number of deposits of importance in this part of the vein.

MINING OPERATIONS IN THE SWEETWATER DISTRICT

Historical statement.—While prospecting for lead in McMinn County in 1840 Colonel R. C. Morris is said* to have discovered an extensive bed of barite "on the west side of a ridge running down between Hiwassee River and Mouse Creek". The bed which he penetrated for twenty feet is said to be "rich and heavy". This is evidently the Shelton deposit described above. By 1874 considerable progress had been made in the mining of barite according to the authors quoted who state that in that year 1,040,177 pounds of barite ore was shipped from several stations of the East Tennessee and Georgia, now the Southern Railroad.

*Killebrew, J. B., and Safford, J. M., Resources of Tennessee, p. 270, 1874.

The first mill was established at Sweetwater during the Franco-Prussian war when the imports of barite from Germany had been cut off. On the establishment of peace the markets were flooded with cheap German ore with which domestic ores were unable to compete on account of excessive freight rates and the industry languished.

In 1899, W. D. Gilman the senior member of the Durex Chemical Corporation who, prior to this had been interested in the barite industry in Baltimore, Maryland, took over a number of leases in the Sweetwater district and began operations under the name of the W. D. Gilman Company. A mill was built in 1903 which has been in almost continuous operation ever since. In 1914 the company was reorganized under the name of the Durex Chemical Corporation with headquarters in Baltimore. The mill was partly burned in March, 1917, but this is being restored and a unit built which will greatly increase its capacity.

About 1903 John T. Williams took over a number of leases and prospected the district extensively. He is said to have worked as many as forty prospects and mines at one time. The low price of ore combined with the high cost of mining and shipping the ore depressed the industry and he abandoned the field in 1908 or 1909.

For the period preceding the present war the production of barite in Tennessee reached its high water mark in 1907, in which year there were mined 20,863 short tons of barite. Of this all but 400 short tons came from the Sweetwater district. The operators of barite mines in Tennessee in that year were as follows:

John T. Williams and Sons, Bristol Virginia.
Mines located near Cleveland, Niota, Reagan, Sweetwater, Philadelphia, Del Rio and Greeneville.
William D. Gilman Company, Sweetwater, Tennessee.
Mines located in Loudon (Dist. No. 5), and near Sweetwater.
Commercial Mining and Milling Company, Knoxville, Tenn.
Mines located near Sweetwater and Del Rio.
J. F. Doherty, Sweetwater, Tennessee.
Mines located near Sweetwater.
C. L. Hudson, Niota, Tennessee.
Mines located near Sweetwater.

From 1907 to 1914 the production of barite in Tennessee declined, the low price of ore making operations unprofitable With the nearly complete cessation of imports in 1914 caused by the war, domestic ores have found a ready market at good prices and there has natur-

ally followed a marked increase in mining activity. Prior to 1907, Greene and Cocke counties were in the list of producers but since that time the entire output of barite in Tennessee has come from the Sweetwater district.

MINING AND PREPARATION FOR THE MARKET

Mining.—The workable deposits being all of the residual type the mining of barite in this district is a relatively simple matter, and has heretofore been carried on by pick and shovel, the ore and clay being removed from the pit in wheelbarrows. There are no pits deeper than 60 feet nor has aditing nor tunneling been practiced. In only a few cases has excavation extended to the limestone below, and no effort has been made to work the original vein by sinking shafts and drifting and stoping. The method that has prevailed mostly in the past is to break the ground by picks, shovel the material into wheelbarrows or dump carts and haul it out for further treatment. The ore separated from the clay by hand is scattered on the ground or on platforms exposed to the heat of the sun, and the rain which will remove most of the adhering clay. The ore is then loaded into wagons with a fork, the smaller pieces going to waste. It is estimated that thirty per cent or more of the ore is lost by this process of handling.

Steam shovels and log washers have been installed in some of the mines with fairly satisfactory results, though in some cases poor results have been obtained owing to poor management. A factor that has to be dealt with, however, is the pockety character of the deposits. All of the deposits are pockety with considerable masses of barren clays. In mining by hand these can be left untouched, but the steam shovel requires their removal; it is doubtful if this method will prove economical in all of the mines. Some recommend* the practice of washing with a 16-foot log washer, crushing and rewashing with a 12-foot washer. Where water is available, by washing at the mines there is a saving of 25 per cent or more in the cost of milling.

The hydraulic method would undoubtedly prove most advantageous in handling these residual clays, but water under sufficient head is not available in the Sweetwater district.

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*Fohs, F. J., Kentucky Geological Survey, Ser. IV, Vol. I, pt. 1, p. 537, 1913.

Preparation for the market.—The preliminary treatment in the preparation of the ore for market comprises handpicking before placing on the dump, screening, handcobbing, grading, washing, crushing, and concentrating. Much of the crude material undergoes only the first three of these processes, viz., picking, screening and handcobbing. This method, however, is adapted only to the coarse material and the large quantities of fine stuff resulting from breakage, and the pebble ore, are lost.

Where log washers are employed, the ore is graded and the finer ores along with the clay inclosing them are sent direct to the washers. Where the product consists of both coarse and fine material in rather large proportions it is usually screened through an inch mesh screen and the lumps removed for handcobbing and the screenings for washing if a log washer is available. The proportion of fine or "gravel" ore is much greater in some mines than in others and hence the installation of the log washer makes possible the operation of mines which otherwise can not be worked with profit.

Only one grade of barite is marketed in the Sweetwater district, viz. the No. 1, or pure white variety. The ore is practically free from calcium carbonate, and manganese oxide and runs 98 to 99 per cent barium sulphate. The silica runs from .30 to 1 per cent and the alumina and iron from .40 to 1.50 per cent. Ore that does not comply with these requirements is rejected. Doubtless much of this might find a market as second and third grade following the classification of the Kentucky report*, according to which the second grade may contain as high as 20 per cent of impurities, such as calcite, limestone, fluorspar, etc., while the third grade includes material that is off-color, usually deeply reddish from iron oxides and running as high as 40 per cent in fluorspar, limestone, calcite, etc. Material of this character of the second and third grades is not regarded as commercial barite in the Sweetwater district. Should a demand for such low grade ore develop, a considerable amount of material now rejected or left untouched would find its way to market.

Most of the mines controlled by the Durex Chemical Corporation are owned by the company. The others are operated in the main under lease. Where worked on royalty the royalty varies from 25 to 75 cents per ton.

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*Fohs, F. J., Kentucky Geological Survey, Ser. IV, Vol. I, pt. 1, p. 536, 1913.

The cobbing may be done by the use of a small hatchet, hack hammer, or pneumatic pick. By this means the larger masses containing iron oxide, zinc blende, galena, or clay, may be freed from most of their impurities and raised to the highest grade.

Transportation.—Haulage is done by wagon and as the roads are only in part macadamized this constitutes an important item in the cost of marketing the ore. During rainy seasons it often becomes necessary to suspend work altogether. The injury to roads and teams would be considerably lessened by the use of wagons with wide tires. The cost for hauling is $4.00 to $5.00 per day for man and team. On the average two mules will haul from 4000 to 5000 pounds per load. Where haulage is by the ton instead of by the day the rate is fixed according to distance in such manner as to make the amount equivalent to the prices paid per day. The cost of labor has increased considerably since the government report for 1915 was prepared.

THE MANUFACTURE OF BARIUM PRODUCTS

The following description of the manufacture and uses of barium products is taken from an article by James M. Hill in Mineral Resources of the United States for 1915, Part II, pp. 181-185, 1916. A footnote to this report states that the sections dealing with manufacture of barium products had been read and criticised by Mr. Hugh Rollin, of the Rollin Chemical Company and Mr. Maximilian Toch, of the Durex Chemical Company:

Ground Barite.—The treatment of crude barite to make ground barite varies in different plants. The general practice, however, seems to be to crush to about 1 inch and log-wash and jig to remove clay, calcite, fluorite, silica, and part of the iron oxide. This cleaned material is next crushed to one-fourth to one-eighth inch at some plants, and at others ground and subjected to a bleaching process. The bleaching, largely to remove iron oxide, is accomplished by treating the material with sulphuric acid from 8 to 12 hours in lead-lined wooden tanks. The bleached product is washed several times and ground in burr mills or pulverizers to pass 200 to 300 mesh, and in some plants is water floated to insure a uniformly fine product, and is then dried, pulverized, and packed. Much care is required not only in the bleaching, but also in the drying operation to insure a uniformly perfect color. Details of the manipulation during bleaching and of the drying machinery are not made public.

The softer grades of barytes are preferred by the grinders, as there is less wear on the machines in treating this class of material. However, in some plants, hard crystalline barite is ground successfully. Several grades of barite

are on the market, varying from unbleached, coarsely-ground material to the finest grade of white-bleached and water-floated pigment.

Lithopone.—Lithopone is a mixture of approximately 70 per cent barium sulphate, 25 to 29 per cent zinc sulphide, and 1 to 5 per cent zinc oxide, which is made by mixing hot solutions of barium sulphide and zinc sulphate. In the preparation of high grade lithopone the solutions of barium and zinc compounds must be essentially pure. The precipitate from the tanks is filter-pressed, dried, subjected to considerable heat, quenched in water, ground to pulp, filter-pressed, dried, and packed for shipment. A recent paper by O'Brien* brings out the important points in the preparation of lithopone and indicates some of the features necessary to produce a light-proof product. Lithopone is sold under a great variety of trade names, such as Beckton White, Green Seal, Blue Seal, Sterling White, Fulton White, Phonolith.

Barium chemicals.—The principal chemicals made in the United States are the binoxide, carbonate, chloride, hydroxide, nitrate, and sulphate or blanc-fixe. Some crude barium sulphide ("Black Ash") is sold to makers of lithopone and manufacturers of chemicals who are not equipped to roast sufficient barite to meet their needs.

As all the barium compounds are poisonous, care must be exercised in their manufacture. Naturally the salts which are only slightly soluble in water are not so dangerous as those which are more soluble. The sulphide is soluble in hot water. The carbonate is sparingly soluble in pure water and is slightly soluble in water containing carbonic acid. The chloride is soluble in water, particularly hot water, but is insoluble in strong hydrochloric acid and alcohol. Barium nitrate is slightly soluble in water, but is insoluble in concentrated nitric acid and alcohol. Barium sulphate is insoluble in water, but is slightly soluble in dilute acids and more so in strong acids.

As there are no published accounts of the actual methods used in manufacturing barium chemicals, and as it is not ordinarily possible to inspect chemical plants, it is not known what methods are actually used in the preparation of the barium salts at various plants. Applied chemistry is, of course, essential to the success of this industry, yet a detailed knowledge of markets, not only for crude materials but also of first products, by-products and labor is of prime importance.

The following notes abstracted in part from Thorp's "Dictionary of Applied Chemistry" and Roscoe and Schorlemmer's "Treatise on Chemistry" are not given as a method of procedure to be followed by those desiring to make barium chemicals, but for general information to those interested but specializing in the subject.

The manufacturers of barium chemicals prefer to use washed, high-grade barite of the soft variety; nevertheless they can, and some do, use barite which could not be used for the highest grades of ground floated barite. The first step in the barium chemical plants is the reduction of the barium sul-

*O'Brien, W. S., A study of lithopone, Jour. Phys. Chem. vol. 19, pp. 113-144, 1915.

phate to the sulphide, which is soluble in water. The barite is finely crushed and mixed with a certain proportion of coal and common salt. The mix varies in different plants, but is generally stated to be about one-fourth coal by volume. This material is fed to rotating furnaces, where it is roasted from three to four hours. The charge is next leached in most plants, first, with a boiling, weak solution of barium sulphide, which is obtained by washing the leached material with hot water. The ash after the leaching and washing is waste, though it may contain some undissolved barium compounds. The extraction of barium sulphide is ordinarily stated to be 70 per cent, though it is known that a higher extraction can be made. The liquid from the barium sulphide leach is stored in large heated tanks, from which it is drawn into the different vats for the preparation of the various salts. Barium sulphide can be precipitated by allowing the solution to cool below 150 degrees F.

The processes of the manufacture of the varius chemicals are intricate and require special study and application of chemical and physical knowledge when done on a commercial scale. The manufacturing chemists do not make public the special methods which they have evolved for the preparation of pure salts. It is known in general that the carbonate and the sulphate can be precipitated from the hot sulphide liquor by the use of appropriate salts of sodium and that a salable sodium sulphide by-product will be formed. It is also known that barium chloride can be made by treatment of the sulphide liquor with hydrochloric acid and by roasting a mixture of barytes, charcoal, limestone, and calcium chloride, but the first precipitate requires purification. Barium nitrate can be made by treating the sulphide solution with nitric acid or by mixing hot saturated solutions of barium chloride and sodium nitrate. The preparation of the binoxide or peroxide (BaO_2) and hydroxide ($Ba(OH)_2$) are said to require a particularly high degree of technical skill, as very high and very low temperatures are required during the course of pro cess and the materials require careful manipulation to insure uniformity. Barium monoxide or baryta (BaO) can be made by heating the nitrate till the evolution of red nitrous oxide fumes ceases, but the heated mass is liable to froth, though this can be prevented by using equal amounts of nitrate and sulphate, which reduces the yield. It can also be prepared from the carbonate by bringing that salt to a white heat when most of the carbon monoxide is driven off. The hydroxide ($Ba(OH)_2$) can be formed by the combination of baryta and water, but as a great amount of heat is evolved, its manufacture in this manner requires considerable care. It can also be produced by passing moist carbon dioxide gas over heated barium sulphide forming the carbonate, after whch superheated steam passed over the carbonate forms barium hydroxide with the evolution of carbon dioxide. The hydroxide can also be made by the electrolysis of barium hydrosulphide. Barium peroxide can be prepared by passing air freed from carbonic acid over baryta (BaO) heated to a dull red, or by treating heated baryta with powdered potassium chlorate, but this peroxide requires purifying.

USES OF BARIUM PRODUCTS

Ground barite of the lower unbleached grades is sold to manufacturing chemists and to paint manufacturers for incorporation in colored mixed

paints; it can also be used in the preparation of rubber and in other industries where a colored product is made. The bleached and floated barite of the finer grades is used as a white pigment in preparation of ready mixed white paints and as a filler for the chemical pigments. In the paper industry it is largely used in the manufacture of heavy, stiff material, such as playing cards, bristol boards, and the like.

Lithopone is sold and used as a white pigment for ready mixed paints, being particularly used for the preparation of what are called the "sanitary flat wall paints" which are used to a large extent. It is also used in some enamels and calsomines, and in the rubber, paper, and cloth industries, where it is replacing barite and some of the metallic pigments.*

The barium chemicals have a wide variety of uses and may enter into the manufacture of other products. In the study of the industry the products have not been followed beyond the plants at which the chemicals are made from crude barite. Barium binoxide, or peroxide (BaO_2) apparently finds its principal market with the manufacturers of hydrogen peroxide, though some is believed to be used in the preparation of oxygen. This salt has the property of giving up part of its oxygen under certain conditions and of recombining with more oxygen under reverse conditions. This property is not, however, everlasting, and fresh supplies of the peroxide are frequently required.

Barium carbonate is used in the preparation of other barium chemicals—in rat poisons, as a water softener, in the manufacture of flat wall paints, and in the ceramic industry. Probably the last is its largest use at present. It is said that this material will fill the requirements of case-carbonizing steel, which was formerly filled by ground bone. Ground bone, which formerly commanded a price of $60 per ton, has risen in price and the makers of case-carbonized steel have been in search of a substitute. The barium carbonate for this purpose must contain no sulphur, but may carry calcium and small amounts of other impurities. It is said the demand should be several thousand tons a year.

Barium chloride is used in the preparation of other barium salts, as a water softener, a chemical reagent, particularly for the purification of table salt, to some extent in the ceramic arts, and in the preparation of rat poisons.

Barium hydroxide is used as a chemical reagent. It can be used in the refining of sugar, but on account of its poisonous nature is not often employed; another reason why it is not used is the difficulty of its regeneration from the carbonate which is formed by the reactions.

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*From Rogers' Manual of Chemistry we learn also that lithopone "does not oxidize progressively, and this single feature has made it invaluable to the table oilcloth and floor oilcloth industry throughout the world. Its indiscriminate use, however, is not to be recommended, and the paint chemist should be permitted to decide when its value is the greatest. As a marine paint, either as a first coat or for making neutral paints where other whites would be necessary, it is found to outlast both zinc oxide and lead carbonate."

Barium monoxide has its principal use in the preparation of the binoxide and hydroxide. It is used to some extent in the manufacture of special glasses.

Barium nitrate is used as a chemical reagent in the preparation of "green fire" and green signal lights and in the manufacture of an explosive known as saxifragin.

Barium sulphate, usually sold under the name of blanc-fixe or permanent white, is a pigment extensively used in the paint industry, in the manufacture of highly glazed papers and of putty, and in the fabrication of rubber and of lake colors.

*Producers**

Companies	Ground Barite	Litho-pone	Barium Chemicals
Barbour Chemical Works, West Coast Life Building, San Francisco, Cal.	+	..	+
Baryta Manufacturing Company, 205 Pearl St., New York City	..	..	+
Beckton Chemical Company, Cleveland, Ohio.	..	+	..
Carolina Baryta Company, Stackhouse, N. C.	+	..	..
Chemical Products Company, 616 Majestic Building, Denver, Colo.	..	..	+
Cherokee Chemical Company, 109 Hollingsworth Street, Baltimore, Md.	+	..	..
Chicago Copper and Chemical Company, 111 West Jackson Boulevard, Chicago, Ill.	..	..	+
Clinchfield Products Company, 120 Broadway, New York City	..	..	+
Durex Chemical Corporation, 320 Fifth Ave., New York City, and Sweetwater, Tenn.	+	..	+
Elkhorn Chemical Company, Elsinore and Gilbert Avenues, Cincinnati, Ohio	+	..	+
J. C. Fink Mineral and Manufacturing Co., 101 Barton Street, St. Louis, Mo.	+	..	..
Globe Chemical Company, 1205 Regent Avenue, Cincinnati, Ohio	..	..	+
Graselli Chemical Company, Cleveland Ohio.	..	+	..
N. Z. Graves Corporation, 22 to 24 South Third Street, Philadelphia, Pa.	..	+	..
Krebs Pigment and Chemical Company, Newport, Delaware	..	+	..
Lamar Chemical Works, 44 to 56 Lewis Avenue, Jersey City, N. J.	..	..	+
Mantua Chemical Company, 350 Grays Ferry Road, Philadelphia, Pa.	..	+	..
Midland Chemical Company, 80 East Jackson			

*Mineral Resources, U. S. Geological Survey, 1915.

Companies	Ground Barite	Litho-pone	Barium Chemicals
Boulevard, Chicago, Ill.	..	+	..
New Jersey Zinc Company, 55 Wall Street, New York City	..	+	..
Nulsen, Klein and Klausse Manufacturing Co., Levee and Sidney Sts., St. Louis, Mo.	+	..	..
Point Milling and Manufacturing Company, Mineral Point Mo.	+	..	..
Port Morris Chemical Works, 141 Locust Ave., New York City	..	..	+
Product Sales Company, 423 to 425 Equitable Building, Baltimore, Md.	+	..	..
Rollin Chemical Company, Charleston, West Va.	..	..	+
Thompson, Weinman and Company, 100 Williams Street, New York City	+	..	..

PRODUCTION AND PRICES

The amount of crude barite marketed in the United States in 1915* was 108,547 short tons valued at $381,032 or an average of $3.51 per ton. This is an increase over the production of 1914 of 52,747 short tons valued at $155,647, or an average increase of .56 per ton. Of this amount Tennessee furnished 25,074 short tons valued at $71,390, or $2.85 per ton. In total output, Tennessee stands third, being exceeded by Missouri with 39,113 short tons, and Georgia with 31,027 short tons.

The prices paid for crude barite in 1915 varied considerably. They were highest in Missouri where $6.27 was paid and lowest in Alabama at $3.56.

Crude barite marketed in Tennessee, 1903 *to* 1916.

	Short tons	Value	Average price per sh. ton
1903a	14,185	$49,618	$3.49
1904a	10,565	37,172	3.51
1905a	7,400	25,545	3.45
1906a	1,754	6,439	3.67
1907a	20,863	45,863	2.20
1908a	7,649	17,075	1.97
1909a	4,631	6,946	1.50
1910a	1,800	2,000	1.11

*Hill, J. M., Mineral Resources of the United States for 1915, p. 162, 1916.

	Short tons	Value	Average price per sh. ton
1911a	4,106	5,079	1.24
1912b	3,718	8,682	2.34
1913b	2,098	3,568	1.70
1914b	10,113	16,273	1.61
1915b	25,074	71,390	2.85
1916b	32,416	123,986	3.85

a. Reports of the Tennessee State Mining Department.
b. Mineral Resources of the United States.

Marketed production of barium products in 1915a

	Short tons	Value	Average price short ton
Ground barite	51,557	$ 635,318	$12.32
Lithopone	46,494	3,760,472	80.88
Barium chemicals	8,823	b	b

a Mineral Resources of the United States for 1915.
b. Not reported.

With the exception of ground and floated barite nearly all the barium products used in the United States prior to 1915 were imported either from Germany, England or France, the industry being best developed in the two first named countries. Ground barite has been produced at various plants in the United States for many years and a small quantity of barium chemicals, but there is no published information of the industry for these years. Following is the production of crude barite in the United States since 1902:

Production and prices of crude barite in the United States, 1903 *to* 1915a

	Short tons	Valuation	Average price per short ton
1903	50,397	$152,150	$3.02
1904	65,725	174,958	2.66
1905	48,235	148,803	3.08
1906	50,231	160,367	3.19
1907	89,621	291,777	3.26
1908	38,527	120,442	3.13

a. Mineral Resources of the United States. The price given is that paid to the miner for the crude ore, hand cobbed, sorted and ready for shipment to the mill. It is not supposed to include the cost of haulage by wagon, boat or railway.

	Short tons	Valuation	Average price per short ton
1909	61,945	209,737	3.39
1910	42,975	121,746	2.83
1911	38,445	122,792	3.19
1912	37,478	153,313	4.09
1913	45,298	156,275	3.45
1914	52,747	155,647	2.95
1915	108,547	381,032	3.51
1916	221,952	1,011,232	4.56

NOTE ON FLUORSPAR

The occurrence of fluorspar in some of the mines of the Sweetwater district has been noted in the foregoing descriptions. Its chief occurrence is in the Howard, Ballard and Minton mines. It appears at certain spots in the ore body associated with barite in varying portions. As its presence lowers the grade of the barite, these places are shunned by the miners. The exposed areas are relatively small and the extent of the deposit of fluorspar is largely a matter of conjecture. A considerable amount of limestone and chert occurs along with the fluorspar and barite and the utilization of the spar is questionable. In view of the demand for this mineral, however, these deposits merit investigation.

Since the fluorspar and barite both withstand weathering better than the limestone or dolomite, the surficial part of the vein containing them remains as a cavernous reef-like mass in the clays, grading below into unaltered vein material. Where the two minerals are easily separated they may be sorted into two products, the one consisting mostly of barite, the other of fluorspar. When ground for mixed paints, or for cold water paints the presence of a small percentage of fluorspar is not harmful since the fluorspar (except with strong sulphuric acid) like the barite remains inert, will grind white, and its triangular-shaped particles will assist in making a more compact film.*

The specific gravity of fluorspar is only a little less than that of barite. According to the author quoted above, fluorspar is helpful as a color extender and is now used to some extent in off-color paints.

*Fohs, F. J., Kentucky Geological Survey, Ser. IV, vol. I, pt. 1, p. 551, 1913.

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VOLUME VIII NUMBER 2

THE RESOURCES OF TENNESSEE

A MAGAZINE DEVOTED TO THE DESCRIPTION, CONSERVATION AND DEVELOPMENT OF THE RESOURCES OF TENNESSEE

PUBLISHED
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STATE GEOLOGICAL SURVEY
NASHVILLE, TENN.

APRIL, 1918

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ANNOUNCEMENT

Election of New State Geologist

BY L. C. GLENN.

After the death of Doctor Purdue on December 12, 1917, Dr. L. C. Glenn of Vanderbilt University proferred his services for attending informally to the correspondence and personal inquiries of the Survey's office until more definite arrangement could be made. On January 10, 1918, the Geological Commission met and elected Doctor Glenn Acting State Geologist to serve until a permanent successor to Doctor Purdue could be secured.

The committee appointed to look up candidates reported to the Commission at a meeting on April 9th and Mr. Wilbur A. Nelson was elected State Geologist.

Mr. Nelson graduated as bachelor of science from Vanderbilt University in 1910 and soon after became assistant geologist on this Survey, which position he held for three years. His investigations during this time covered a wide range of subjects, among which may be mentioned especially, building sand, caves, coal, clays, iron ore, lead, lignite and manganese.

Mr. Nelson then spent a year's leave of absence in graduate study at Leland Stanford University, where he took the degree of Master of Science in 1914. He was elected to membership while there in the honorary scientific society Sigma Xi. Following this he returned to the Survey, but later resigned to become geologist for the N., C. & St. L. railway. After nearly two years he gave up this work to accept a responsible position with the Paga Barite Mining Company at Cartersville, Georgia, and was connected with this corporation when elected State Geologist. He has also done special work for the Southern Manganese Corporation and other mining concerns. His mining and other affairs will prevent his assuming active charge of the Survey before May 1st.

Mr. Nelson comes to the Survey already familiar with its organization and operation and with a knowledge of the State's mineral resources and the possibilities of their further development that will stand him in good stead in continuing the State Survey on the high plane on which Doctor Ashley originally pitched it and Doctor Purdue subsequently maintained it.

Report on the Caves of the Eastern Highland Rim and Cumberland Mountains

By Thomas L. Bailey

During the two months from July 15 to September 15, 1917, the writer explored 109 caves and rock shelters in the eastern part of Middle Tennessee. All except eight of these were caves, these eight being what are known as rock shelters or rock houses. This work was done to determine the value of these caves as possible sources of niter. A sample of the earth was collected from different parts of the floors of all the caves and rock shelters where there were sufficient accumulations of earth to work in case it should contain a fair percentage of niter. From large caves two samples were sometimes collected. These samples were numbered and labeled in accordance with the numbers given to the caves and rock shelters in this report. The descriptions of the individual caves and shelters contained in this paper are generally arranged in the following manner: (1) the location, both geographic and geologic; (2) the topography of the mouth and its surroundings; (3) the dimensions of the cave as nearly as can be approximately estimated; (4) a description of the interior, including the important point of whether there is a running stream in it or not; (5) the average depth of any loose earth on the floor; (6) a description of the stalagmites, stalactites, rock-rimmed pools, terraces, and other water-deposited limestone formations; (7) the use of the cave or rock shelter as a burial ground by Indians, if such were possible to determine, together with other facts of historic interest. This order is frequently modified or changed, but it is followed in the majority of cases. These samples of earth were sent to the Survey's Chemist for analysis soon after being collected. In this investigation there was not sufficient time to go to all caves in the counties visited, but the attempt was made to investigate those which would probably be of most value for deposits of niter. Information concerning the location of these caves was largely gathered from the inhabitants of the region, and very likely some important caves were left unexplored. Those which were explored, however, are believed to be typical representatives of the caves in the region. With

the limited amount of time, naturally much of the information here given is only approximate.

The descriptions are given by counties arranged alphabetically. The results of the chemical analyses follow in a brief article by Dr. L. C. Glenn.

CLAY COUNTY.

No. 18. Bailey Cave.

Location.—On the farm of Ben Bailey, 5 miles south of Celina; one-fourth of a mile north of Bailey's house, near the foot of the mountain, on the east side and near the head of a small hollow. It is in the Ordovician limestone about 65 feet below the Chattanooga black shale. It is 300 yards from the Celina road and two miles from the Cumberland River.

The entrance is in thin woods just above an open pasture, and is a vertical hole extending downward for a distance of 20 feet or more and then turning eastward and northeastward. There is a small stream flowing through the cave except near the mouth where it passes beneath the floor. This is not a very large or spacious cave but it is quite long and sinuous, being about a half mile in length. It averages about 6 feet in width and 8 feet in height. There are three rooms of considerable size located at intervals along the cave. At a distance of 300 yards from the mouth and extending back for 100 yards is a bed of loose earth 6 feet thick that contains sparkling crystals of gypsum. There are some other banks of loose earth farther back in the cave. Stalagmites and stalactites are scarce. About one-fourth mile or more from the mouth are some stones with grains of blue corn lying on them that were thought to have been left by the Indians.

No. 19. Saltpeter Cave (Rock Shelter).

Location.—On the farm of Irving Abner, 5 miles southeast of Celina, one-half mile north of Abner's house, 200 yards from a log house at the head of the west fork of the hollow. It is 100 feet below the top of the mountain and a half mile from the public road. It is in Mississippian limestone, 20 feet above the Chattanooga black shale.

This is really more of a rock shelter than a cave, although there are openings in the limestone at the back of the shelter that extend into the bluff about 100 feet in some cases. However, these openings are only 4 feet high and 3 feet wide. The rock shelter is 20 feet high and 100 feet wide and extends back about 100 feet, making an enormous hole

in the side of the mountain. The earth on the floor is not over one foot thick on the average and contains a thin, white crust of niter.

No. 20. Daly Cave.

Location.—On the farm of Thomas Daly, 4½ miles northeast of Butler's Landing on the Hilham road. It is a very large cave according to reports and during the Civil War saltpeter was obtained from it. Hoppers where it was leached from the cave earth are still in existence. This cave was not visited but several people gave similar reports of it. It probably still contains a fairly large quantity of niter.

No. 21. Sheals Cave.

Location.—On the farm of Ed. Fowler and his partners, a half mile northeast of Celina near the base of a hill above a large spring in pasture land about 100 yards from the public road. It is in Ordovician limestone. The mouth is on the edge of an open pasture beneath a projecting ledge of rock, which forms the roof farther in. The mouth is closed by a wooden gate and potatoes and other produce are stored in it in the winter. A stream runs throughout almost the entire length of the cave. It is quite large at the mouth and the large chamber extends back about 100 feet. Then it becomes low and narrower. The roof is almost flat. The mouth is 8 feet high and 12 feet wide while the main chamber is 15 feet high and 40 feet wide. There is little loose earth but no stalactites.

No. 22. Rich's Cave.

Location.—Five miles northeast of Celina on the land of Grover Rich, a fourth of a mile west of Rich's house, and two-thirds of the distance to the top of the mountain, at the base of a limestone bluff 30 feet high. It is a quarter of a mile from the Pea Ridge road and a half mile from Obey River. It is in Mississippian limestone, 30 feet above the Chattanooga black shale.

The mouth of the cave is very large and the roof is an overhanging ledge of arenaceous limestone. It is in thick timber and is 10 feet high and 25 feet wide. A small stream flows through the cave, which extends back over 200 yards, but gets too low at the end of 100 yards to penetrate any farther. The average height is 5 feet and the width 8 feet. On both sides of the stream there is loose earth about 3 feet in thickness. This earth is sandy, and there is much sand in the bed of the stream. There are very few stalagmites or stalactites.

No. 23. Williams Cave.

Location—This is a small dry cave on the land of Mrs. M. Williams 4 miles northeast of Celina at the base of a limestone bluff 25 feet high, in thick woods. This cave is so small that it is hard to penetrate and does not seem to contain much loose earth. Its height is 5 feet and its width 4 feet or less. There are a few stalactites.

No. 24. Roundmouth Cave.

Location.—On the land of Ance Key, 5 miles northeast of Celina, about 1½ miles south of Key's house, and three-fourths of a mile northeast of Grover Rich's house in thick woodland near the top of the ridge. It is about a quarter of a mile from the Celina-Lillydale ridge road. It is in Mississippian limestone, 20 feet below the Lee sandstone.

The mouth is a round hole about 4 feet in diameter, that extends downward almost vertically for 25 feet. The cave extends in a northerly direction. There is no stream, but water drips from the roof in many places, and the interior is very cold. This cave is straight and light from the mouth, can be seen back for 150 yards, beyond which point it can not be penetrated easily. It averages 10 feet in height and 6 feet in width.

The loose earth on the floor is rather sandy and averages 3 or 4 feet deep, though in some places it is much deeper while in others the floor is of limestone. The cave formations are very abundant and beautiful and the faint greenish light that enters through the mouth gives the numerous white stalactites, stalagmites and natural columns a very ghostly but attractive appearance. The stalactites and stalagmites arranged regularly along the walls together with the maze of natural columns and slender stalagmites and stalactites at the back of the cave give that part the appearance of a church with its altar at the back.

No. 25. Webb Cave.

Location.—On the farm of W. C. Webb, 4½ miles east of Celina, 100 yards northeast of Webb's house. It is in Ordovician limestone at the foot of the ridge, 30 feet below the Chattanooga black shale. The limestone is rather sandy.

The mouth is roughly triangular. The cave is 10 feet wide and 5 feet high and extends northeastward for a short distance when it gets too low to penetrate. The walls are very smooth and the curves in the cave are at right angles following the joint planes of the sandy lime-

stone. There is little loose material on the floor and a stream flows along it so that any niter has probably been removed.

DeKALB COUNTY.

No. 72. Saltpeter Cave.

Location.—One fourth mile east of Temperance Hall on the land of Dr. Skiler Robinson. It is in the Ordovician limestone 50 feet below the Chattanooga black shale.

The mouth is a round hole in an old field near the top of a low hill in the edge of thin woods. It extends straight down for a distance of 35 feet and then opens into a rather large room. The cave is damp but no regular stream flows through it. It is 500 yards long, 20 feet wide and 25 feet high and is rather winding. There are several banks of clayey earth that are 15 feet high, while the average depth of earth for the cave is about 6 feet. In places the earth is coated over with calcite. There are two very large and beautiful columns fully 30 feet high where the stalagmites and stalactites have only recently met. They are parallel and joined together at the top and base. At the base their thickness in one direction is 20 feet and they are situated on top of a rounded mound-like stalagmite that covers the floor for 50 square feet or more and is about 7 feet high. The whiteness of these columns adds much to their beauty. There are several other thick, inverted-cone-shaped stalagmites at various places, some of which are very pretty. There are also some fringes of stalactites at several points that add to the attractiveness of the cave. The back of the cave seems to be blocked by formations of this kind. There are evidences of former work in the cave. Marks of shovels may be seen in the banks of earth, and there are pieces of old troughs. It is said that gunpowder was once made in this cave.

No. 73. Snow Hill (Saltpeter) Cave.

Location.—Two miles southeast of Dowelltown on the land of Mrs. W. P. Banks, 200 yards south of her house near the foot of Snow's Hill on the edge of a thin woodland about 100 yards from the Smithville pike. It is in the Ordovician limestone over 200 feet below the Chattanooga black shale. The mouth is at the west end of a pit-like hole about 8 feet deep and 50 feet wide. The mouth is wide and rather low, being about 6½ feet high and 40 feet wide. It is a nearly dry cave, but the earth is damp. The average width of this cave is 20 feet and

the height is 10 feet. It is about a half mile long, although there are some narrow places through which it is necessary to crawl. It is said to open on Dry Creek over a mile away from the mouth. There is a large amount of loose earth on the floor that has been excavated to a depth of 8 feet in places, while the average depth is probably 5 or 6 feet. There are marks of tools in this earth and also remains of old metal troughs. Stalactites are numerous but none are very large.

No. 74. Jim Cave.

Location.—Two and a fourth miles south of Dowelltown on the land of B. W. Robinson, 200 yards north of Don Williams' house, 100 feet below the top of the hill facing Dry Creek, and between the Smithville Pike and Dry Creek. It is in Ordovician limestone, 150 feet below the Chattanooga black shale.

The entrance is under a low bluff of limestone in a thick grove of young trees. It is only 4 feet wide and 3 feet high and hence is very hard to find. It slopes downward rather steeply for 30 feet. The earth is rather damp but there is no running or standing water present. The cave is 400 yards long and averages 15 feet in height and 10 feet in width. The earth in the cave is in banks 6 feet or more in thickness. The cave is named for a negro, Jim, who killed a man and hid himself here for some months before being apprehended. In the branches of this cave there are a large number of bones, some of which may be human. There are also some very beautiful calcite and aragonite formations, especially near the back of the cave, and a few of the stalactites are rather large. There is one very high and slender stalagmite.

No. 75. Myers' Cave.

Location.—Two miles southeast of Dowelltown on the land of A. R. Myers, 200 yards east of his house, and 200 yards from the Smithville-Liberty pike. It is in the Ordovician.

The mouth is located about 100 feet from the base of the hill near the edge of a grove of cedars. It is 20 feet long and 6 feet wide and opens vertically downward for 25 feet. There is no running water present but there are pools of standing water and the earth is muddy in places. The mouth opens into the main room which is 200 feet long, 50 feet wide and 20 feet high. Three branches lead off from this room, one being about 25 feet above the floor of the main room. The average width of the branches is 12 feet and their height 6 feet. All three are

about 50 or 60 yards long and become low at their ends. The loose earth is mostly in these branches and is about 4 feet deep. In the main room the earth is muddy and mixed with rocks but it is probably 4 or 5 feet deep. There are a few pretty stalagmites and stalactites especially in the upper or northern branch, which is reached by means of a ladder. There are evidences of digging in some of the banks of earth.

No. 76. Gin Bluff Cave.

Location.—One mile north of Dowelltown on the land of J. B. Stone near the foot of Gin Bluff about 100 feet above Smith Ford. It is in Ordovician limestone.

There are two mouths to the cave connected by a curved passage. The north mouth is larger and is called the wet mouth since a large stream of water, which forms a series of rapids in its course to South Fork, flows out of it. The south mouth is dry and arch-shaped and is about 10 feet high and 7 feet wide at the base. The wet mouth is 30 feet wide and 6 feet high. These mouths are located just above the strip of woods and at the base of a bare limestone bluff 150 feet high. There are two forks to the cave, the Dry Fork, which connects the dry and wet mouths, and the Wet Fork, which follows the underground branch. From the wet mouth to where the Dry Fork branches off, the floor of the cave is covered with a series of clear pools of water, some of which are 4 feet deep and separated by thin wavy-edged limestone partitions. The mud in the stream in front of the mouth seems to have been calcified only recently, so that it is now possible to walk on it though it looks as if it were boggy. The rock-rimmed basins in this cave are some of the largest and prettiest examples of this type of deposit that were seen in any cave visited. The stream occupies most of the floor of the Wet Fork so that niter is not present. The earth on the floor of the Dry Fork, however, is probably 5 feet deep and is whitish in color, probably containing niter. This fork is about 300 yards long and averages 15 feet in width and 8 feet in height. The Wet Fork is over a quarter of a mile long and is wider but not so high. In the dry mouth there is a large pile of ashes 6 feet deep, from which an Indian skeleton was dug up.

No. 77. Robinson Cave.

Location.—Four hundred yards southeast of Dowelltown on the land of J. A. Robinson, 200 yards below the top of the hill in an open pasture at the foot of a beech tree. The cave is in Ordovician limestone about 200 feet above the bottom of the hill.

The mouth is 12 feet long and 7 feet high and slopes downward at a steep angle. The cave consists mainly of one large oblong-shaped room 400 feet long, 100 feet wide, and 50 feet high. Toward the back of this room there is a high pile of broken rocks and one small passage leads straight west, but it is too low to penetra sily. This narrow passage seems to open into another room. T e is little loose earth on the floor and it is mostly mixed with bowl. rs. There is a large group or series of groups of wonderful stalactites, stalagmites, columns, terraces and pools separated by high, thin partitions near the top of the high pile of rocks near the south side of the room, and these calcite deposits have cemented the rocks into a breccia in places. One group of slender stalagmites and columns is arranged like the pipes of an organ, but most of them are short and thick but wonderfully symmetrical. Some have acorn-shaped knobs at their extremities.

No. 78. Williams Cave.

Location.—Three-fourths of a mile southeast of Dowelltown on the farm of J. B. Williams, 400 yards northeast of Williams' house, and about the same distance from the Smithville pike, in the Ordovician limestone.

The mouth is 75 feet below the top of the hill and is near the top of of a high bluff east of a broad, cultivated bottom. The mouth is under an overhanging ledge of limestone and is 4½ feet high and 10 feet wide. It is in thin woods that are full of bowlders making it hard to find. The roof of the highest part is only 7 feet high and it gradually becomes lower farther back. It is 25 feet wide and 200 yards long. The loose earth is a little damp and is about 5 feet deep. The cave slants backward slightly and is said to open on the other side of the hill but is too low to penetrate much more than 200 yards. It extends northeast and there are very few curves in it. The roof is practically smooth and seems to be a bed of cherty limestone. This cave is 400 yards from the Smithville pike.

No. 79. Williams Cave.

Location.—One and a fourth miles southeast of Dowelltown on the farm of Mrs. Rachel Williams, a fourth of a mile northeast of her house. It is in Ordovician limestone about 300 feet below the Chattanooga black shale. This cave is only a half mile from the Smithville pike and 200 yards from a public road, and is very easily accessible for the land

between is quite level. The nearest railroad is the Tennessee Central at Watertown, which is about ten miles distant. The Caney Fork is 8 miles east of the cave.

The mouth is a very inconspicuous hole in a small hollow in open pasture land, covered over with cedar brush to prevent cattle from falling into it. It is about 3 feet in diameter and extends straight down for 20 feet. Some dirt has fallen in from above so that it is possible to enter the cave without a ladder. There are two principal forks to this cave and each extends more than a mile, possibly 2 or 3 miles, though there are a few low places. One fork extends southeast and the other north. They are both large, averaging 25 feet in width and 12 feet in height. There are a few rather large, rock-rimmed pools of clear water which are 3 feet deep in places and about 5 feet in diameter, such as those described for numbers 76, 69 and 37. The water with which they are filled drips from the roof. The earth in the north fork is rather damp but much of that in the southeast fork is practically dry and consists mainly of a stiff yellow clay. About a fourth of a mile back in the southeast fork and continuing for a considerable distance the earth as well as the rock walls and roof of the cave are coated with prismatic, needle-like crystals of gypsum which sparkle like thousands of diamonds. This coat of crystals averages about one-half inch in thickness, although in places it is as much as 4 inches thick and very clear and beautiful. The majority of these crystals are more or less discolored on the outside by mud. Internally they are fibrous and have a silky luster. Small crystals of the same mineral can be seen sparkling in the loose earth. The earth which has been dug considerably during Civil War times is probably 10 feet thick in this part of the cave, though the whole cave will average only about 5 feet. There are remains of some old hoppers where the niter was separated from the earth, though metal troughs seem to have been mainly used. The hoppers are in a poor state of preservation but were similar to those described under No. 53. There are some beautiful stalactites and stalagmites in this cave but none are very large.

No. 80. Johnson Cave.

Location—Six miles southeast of Smithville on the land of W. M. Johnson, on the west bluff of Caney Fork, a half mile northeast of Johnson's house. It is in Ordovician limestone, 25 feet above the river.

The mouth is in thick woods on the bank of the river about 100 yards east of a small ravine that leads from near Johnson's house to the Caney

Fork. The entrance is 30 feet wide and 8 feet high and slopes very slightly downward. It is under an outcropping bed of limestone 5 feet thick. This cave is quite large and extends over a mile in a northwesterly direction. It averages 40 feet in width and 15 feet in height. The loose earth is heaped up in high banks and mounds and probably averages 8 feet, but it looks as if it had been washed over by water. There are few stalagmites and stalactites and the earth is a stiff yellow clay. There are a large number of branches and men have been lost in this cave for some hours. There is no regular stream within the cave for a mile from the mouth.

No. 81. Allen Cave.

Location.—Six miles southeast of Smithville on the land of Lou Allen about a fourth of a mile east of Razzie Redman's house on the bluff of Fall Creek. It is in Ordovician limestone.

This is a small cave with a rock bottom and of no importance economically though it is quite pretty, having a number of stalagmites and some pools of water. Some of these are large and there is one large natural column. It is only 5 yards long, 5 feet wide and 7 feet high.

FRANKLIN COUNTY.

No. 88. Keith Cave.

Location.—On the farm of T. A. Keith, 3 miles southeast of Cowan, one-fourth mile northeast of Keith's house near the head of Keith Cove. It is a fourth of a mile from the road and 3 miles from the Nashville, Chattanooga & St. Louis Railway. It is in St. Louis limestone, 700 feet below the Lee sandstone. It is in woods about 200 yards from the foot of the mountain. The mouth is small and it is necessary to crawl 150 feet to get into the large part of the cave. The cave consists mainly of one large room which contains hundreds of various-sized natural columns. Some are 5 feet in diameter while others are 20 feet long and only 5 inches in diameter, and others are even smaller. There are also stalagmites resembling waterfalls or rapids, cones or inverted bowls, rugged masses of various shapes as well as a few rather tall slender ones. The stalactites hang in groups of all shapes and sizes and vary from a few inches to 30 or 40 feet in length. The floor is covered almost entirely with a thick coat of calcite and there are rock-rimmed pools of clear water in many places as well as many such basins that contain no water. In many places prismatic crystals have formed on the outside of these formations and sparkle like thousands of brilliant

gems. There is practically no earth on the floor but the crust of calcite sounds somewhat hollow and probably there is cave earth beneath the crust. This cave is about 400 yards long, 100 yards wide and 50 feet high. There is a light hole in the roof of the main room near the center. The formations have been badly mutilated, the smaller ones having been broken off.

No. 89. Little Cave.

Location.—Two and a half miles northeast of Cowan on the farm of Ed Garner, near the foot of the mountain a fourth of a mile northeast of Garner's house on the side of Miller Cove. It is in Mississippian limestone, 800 feet below the Lee sandstone.

The mouth is in the woods near the foot of a small mountain between Miller and Hawkins Cove. It extends downward for 30 feet, then southwest and south for 150 yards. It averages 25 feet in width, 15 feet in height and has no stream in it. There is very little loose earth, and what there is is mixed with large slabs, except in the back of the cave, where there is a large room with a level earth floor. There are heaps of rocks near the mouth. The loose earth probably does not average over a foot in depth. There are several stalagmites and a few small stalactites in this cave.

No. 93. Tally Fork Cave.

Location.—Three and a half miles south-southwest of Sewanee near the head of Talley's Fork at the head of a branch hollow south of the main hollow, on the old Stewart tract, southwest of Joe Milburn's house. It is about a mile from the nearest road and 3 miles from the railroad. It is in St. Louis limestone, 100 feet below the Lee sandstone.

The mouth is in thick woods under a limestone bluff 25 feet high and is wide and rather low and extends downward at a considerable angle. The cave is about 40 feet wide and 5 feet high. It extends west for 150 yards and consists of one main room that is 300 feet wide and 7 feet high. On the north side of the mouth there is a large mass of stalagmites of considerable size that resembles in places a series of waterfalls. At the back of the main room there is a bank of earth and small rock fragments 4 feet deep that has been worked for niter. There are remains of old hoppers.

No. 94. St. Mary's Cave.

Location.—One and a half miles south-southeast of Sewanee, a fourth of a mile northwest of St. Mary's station on the land of the University

of the South. It is situated in Mississippian limestone, 40 feet below the Lee sandstone.

The mouth is in thick woods, 100 yards below the railroad, at the base of a limestone bluff 25 feet high. The cave is small and contains no earth. A small stream runs through it. It is 150 yards long and averages 4 feet in height and 8 feet in width. It is very recent in formation and there are no stalagmites.

Hell Hole (Hawkins Cove) Cave.

Location.—Three miles southeast of Sewanee on the University of the South's land near the head of the west fork of Hawkins Cove, on a point 125 feet high between two ravines below Clara's Point. It is in St. Louis limestone, 150 feet below the Lee sandstone, two-thirds the way up the mountain.

The mouth is a rather large, irregular hole in the mountain opening vertically downward. Near the mouth there is a large bowlder of limestone that is almost balanced, having been undermined by water. The entrance is on a bench on the mountain. The hole extends down for 60 feet and opens up below into a room 100 feet long and 75 feet high. There is only one small passage 150 yards long, 4 feet wide and 7 feet high that extends in a northerly direction from the main room. In the main room there are huge piles of broken rock which slope downward steeply toward the back. The main passage of the cave seems to extend downward farther but it is stopped up by these broken rocks. Below the rocks near the edges of the room are banks of yellow clay 15 feet deep. There is also a little earth in the narrow side passage. There are very few stalactites.

No. 96. Wet Cave.

Location.—Two and a half miles northwest of Sewanee near the head of Rowark Cove on the west side of the cove on the land of Buck Crownover, 50 yards south of Crownover's house. It is 100 yards from the public road and 2½ miles from the railroad. It occurs in Mississippian limestone, 800 feet below the Lee sandstone.

The mouth is in an open pasture at the foot of the mountain and below a bluff 10 feet high. The mouth is 8 feet high and 6 feet wide and a small creek flows out of it. There is an exceptionally strong breeze that comes from the mouth which is quite cold in summer and warm in winter. The cave is at least a mile long and smaller just inside the

mouth than farther back. There are many curves and crooks in this cave, especially near the mouth. The cave is 20 feet wide and 10 feet high. About 100 yards from the mouth a ladder leads to a ledge above the stream but the stream is reached a short distance farther back. On it there is a waterfall and just above this fall there is a peculiarly symmetrical and smooth-sided pot hole. At one place it is so low that stooping is necessary. At this point the stream flows beneath the floor. Beyond there the roof is higher and the stream appears again. It is necessary to crawl through a small round hole, called Fat Man's Misery in order to reach a large room called Angel's Chamber, which has many small stalactites and stalagmites in it. There are banks of earth along the stream in most places that are 8 feet or more in height.

No. 97. Dry Cave.

Location.—Two and a half miles southeast of Sewanee about a third of the distance up the mountain, on the University of the South's land, on the east side and near the head, of Rowark Cove about a mile east of cave No. 96. It is in St. Louis limestone about 500 feet below the Lee sandstone.

The mouth is at the south end of a very large sink-hole which is fully 60 feet deep. The entrance is low and wide and slopes down over broken rocks for about 25 feet. The cave consists mainly of one large room that averages 200 yards in length, 100 yards in width, and 25 feet in height. There are a large number of natural columns that are 25 feet high and 6 feet or more in diameter. The stalactites and stalagmites are abundant but have been smoked by fires built in the cave. The cave is damp. Water drips from the roof though no regular stream flows through the cave. The earth is 4 or 5 feet deep, much of which has probably been washed in from the sink-hole.

No. 98. Lost Cove Cave.

Location.—Nine miles southeast of Sewanee, 3 miles northeast of Sherwood, near the head of Lost Creek Cove and near the foot of the mountain. It is in Mississippian limestone, 800 feet below the Lee sandstone.

The mouth is about 15 feet high and 30 feet wide and above it is an imposing limestone bluff fully 175 feet high which overhangs the mouth. The bluff with the mouth below it is the most imposing and wonderful part of this cave. A rather strong breeze comes out of the

mouth and Lost Creek flows through the cave. This cave is about 2½ miles long and averages 40 feet in width and 30 feet in height. The interior of the cave is very rough and for nearly its whole length there are great heaps of broken rocks piled up on one side or the other of the cave. In many places there are banks of earth and broken rock 20 to 25 feet high. Lost Creek, which flows through this cave, averages 10 feet in width inside the cave and there are many waterfalls and rapids along it. There are no stalagmites or other formations in the main part of the cave, although in some of the small side branches near the mouth there are a few. In one of these branches there is a very beautiful series of rock-rimmed pools. Far back in the cave there is a bat roost. It is said that niter has been mined in this cave and signs of digging can be seen near the second mouth. Besides the mouth where the stream enters there are two other mouths to the cave which enter it almost vertically.

No. 99. Saltpeter Cave.

Location.—Two hundred yards south of Lost Cove Cave and 150 feet above it. It probably is connected with No. 98 by small passages. It consists mainly of one room 20 feet in width, 100 feet in length and 8 feet in height, which contains a good many stalagmites and stalactites. The mouth is low and slit-like. The walls and stalactites are coated in many places with a crust of white, powdery gypsum or niter. The earth in the cave does not average over 6 inches in depth.

GRUNDY COUNTY.

No. 90. Wonder Cave.

Location.—At the foot of the mountain 3 miles north of Monteagle on the land of Mrs. R. M. Payne at the Monteagle pumping station.

There is a good road up the mountain to Monteagle and the Nashville, Chattanooga & St. Louis Railway is about 3 miles distant. Many people visit this cave. It is in Mississippian limestone, 800 feet below the Lee sandstone.

The mouth used by visitors is artificial. The entire width of the natural mouth is occupied by a stream 3 to 5 feet deep, whose surface is within 3 feet of the roof. The cave was discovered by accident by somebody wading in the creek. The artificial mouth was blasted out to allow easy entrance for visitors. This cave is probably the greatest show cave in the State. It is lighted with acetylene gas. The cave is very large and is said to extend for 3 or 4 miles along the stream. It

has been explored for 2 miles, though it is necessary to wade in some places in order to enter farther than three-fourths of a mile. The main stalactite and stalagmite room is about a half mile from the mouth and is separated from the main cave in all but two places by an irregular partition of limestone. The cave averages about 40 feet in width and 12 feet in height. The stream that flows through it is a good-sized creek. In many places there are large banks of yellow, clayey earth along the stream. These are 12 feet or more in height and a rod or more in width.

The main stalactite room is about 400 yards long, 100 yards wide and 8 feet high. The floor is very smooth and white and is composed of solid calcite deposited by water. In this room are thousands of stalagmites, stalactites and natural pillars of all shapes and sizes. The natural columns are unusually abundant and some are 4 feet or more in diameter, while there are a few which are 8 feet high but only an inch in diameter. Others are very grotesque and weird in shape, with fancied resemblance to various objects. The stalagmites are especially wonderful and grotesque in shape, those near the walls being unusually beautiful and varied in form. The stalactites are characteristically long and slender and give the effect of white drapery. The whole roof of this room is studded with them. There are a few very large and massive stalactites. Some of them fail to touch the stalagmites below by only a few inches while in a great many other cases the floor below them is smooth and level. Many of these formations are so white that they resemble porcelain ware, while some are made up of many tiny calcite and aragonite crystals brilliantly irridescent and sparkling. Near the center of the room there are also several rock-rimmed pools of clear water. Some of the most picturesque formations in the cave are the many little round grotto-like places separated from the main room by a drapery of long slender white stalagmites. Some of these stalactites and stalagmites give a musical note when struck. In the number of stalactites this cave far surpasses any other cave visited, although Keith Cave, No. 88, would nearly equal it if these formations had not there been largely broken off.

No. 91. Crystal Cave.

Location.—Three and a half miles north-northwest of Monteagle on the land of Mrs. R. M. Payne, 300 yards west of the mouth of Wonder Cave, in St. Louis limestone.

The mouth is situated 20 feet north of the road in a small hole or depression about 15 feet deep. Stone steps lead into the cave. The mouth is 5 feet wide and 6 feet high and is barred by a wooden gate. The cave is about a quarter of a mile long, 15 feet wide and 5½ feet high. There is a small spring just inside the mouth and a little stream flows to the back of the cave. The banks of earth on both sides of the cave average 4 feet in depth. Rocks are mixed with the earth.

There are some beautiful formations in this cave many of which are coated with a white powder, possibly niter. Two human skeletons were dug out of the earth at the mouth. There is an ash heap here about 6 feet deep.

No. 92. Saltpeter Cave.

Location.—Five miles northwest of Monteagle on the farm of Shak Rollins near the head of the cove on the opposite side of the ridge from Wonder Cave, a quarter of a mile south of Rollins' house. It is 500 yards from the public road and 5 miles from the railroad. It is in St. Louis limestone, 600 feet below the Lee sandstone and about 100 feet from the foot of the mountain.

The mouth is a round hole 3 feet in diameter, in thick woods near the base of a limestone bluff 25 yards from a dim road. The cave extends in a southwest direction for 300 yards. It is small, averaging 5 feet in height and 6 feet in width. It contains a loosely cemented breccia which is mixed with much earth and averages 4 feet in depth. In places holes have been dug in this material and the earth removed for making niter. There are no stalactites.

No. 100. Coal Mine Rock Shelter.

Location. — Three and a half miles northeast of Monteagle, near Clouse Hill Junction, a half mile north of Dr. Lillian Johnson's house. This shelter is formed by the rapid weathering of a bed of shale between the top of the Mississippian limestone and the base of the massive Lee sandstone.

This shelter is the site of a former coal mine. The shelter is 300 yards long, 6 feet high, and 7 feet wide on the average. The earth on the floor is about 4 feet deep. In several places this earth is coated with pure alum a half inch thick and there seems to be some niter present also.

No. 102. Peter Rock Cave.

Location.—Three and a half miles southeast of Beersheba Springs on the land of D. H. Savage on the east side of Pound Gulf and near

its mouth, 50 yards above the foot of Peak Mountain. It is situated in St. Louis limestone, about 800 feet below the Lee sandstone.

The entrance is at the base of a limestone bluff 25 feet high at the head of a small hollow in the woods near an old field, a short distance south of the junction of Pound and Savage Gulfs. There are two small mouths which are only 6 feet apart and extend in different directions at first but finally converge. The main mouth is only 3 feet in diameter. There is no stream in this cave but the floor is damp and in some places muddy. For about 50 yards inside the mouth the cave in only 3½ feet high and 4 feet wide, but after climbing down a low precipice, a good-sized cave is reached. From this point on, the cave extends about 200 yards farther and averages 15 feet in width and 12 feet in height. Several small passages lead in various directions from the main cave. The earth on the floor averages 5 feet or more in depth. There are many beautiful stalagmites and stalactites and a few large natural columns. Several little side rooms are almost completely shut off from the main cave by natural columns and stalactites. Some of these formations are very attractive.

No. 103. Big Bear Cave.

Location—Seven miles southeast of Beersheba Springs, on the land of Joe Dickens, on the east bluff of Savage Creek, about 4 miles north of the head of Savage Gulf near Jumping Water Branch. It is in St. Louis limestone about 500 feet below the Lee sandstone.

The mouth is on the steep bluff of Savage Creek 100 feet above the creek in the thick, wild woods. 300 yards south of Jumping Water Branch. It is situated at the base of a limestone bluff 15 feet high and is only 3 feet high and 5 feet wide. There are three other small entrances near this one. The cave contains no niter but is quite dry. It is exceedingly intricate and full of intercommunicating passages which form a labyrinth in which it is easy to get lost. There are several small holes in the floor that are 50 feet or more in depth. The earth is fully 10 or 12 feet deep. In some places holes have been dug and the earth removed. The main cave is over a mile long and several lateral passages are as much as a fourth of a mile long. The average height is 8 or 10 feet and the width about 8 feet. There are some very beautiful stalactites, stalagmites, limestone terraces, and natural columns in this cave, some of which ring like bells when struck. This cave is very hard to find. D. H. Savage and Elliott Adams who live near Beersheba Springs are practically the only people that know where it is. It is

rather inaccessible and any material mined would have to be hauled to the top of the mountain by a cable, probably. The nearest railroad is about 13 miles away, at Coalmont.

JACKSON COUNTY.

No. 9. Saltpeter Cave.

Location.—In the bluff on the north side of the Cumberland River on the farm of J. T. Draper, a fourth of a mile west of Draper's house 1½ miles south of Gladdico. The cave is in Ordovician limestone, a third of the way up the bluff. It is a fourth of a mile from the public road and a half mile from the Cumberland River.

The mouth of the cave is 5 feet by 5 feet and overlooks a broad bottom which is cultivated. The bluff is thinly wooded below the mouth but there is a perpendicular limestone ledge above it. The cave is small, extending only about 50 yards, and is quite dry inside. It averages 30 feet in height. The loose earth on the floor is 5 or 6 feet deep and contains bones, possibly of Indians.

There are practically no stalactites or stalagmites in it. The end of the cave seems to be filled up with loose earth.

No. 10. Burial Cave.

Location.—A fourth of a mile north of Flynns Lick on the farm of Joshua Haile, Sr., in the low west bluff of Flynns Creek. The mouth is only 200 yards west of the Gainsboro road and about 2 miles from the Cumberland River. It occurs in Ordovician limestone, 300 feet below the Chattanooga black shale.

The mouth is in the west bluff of the Creek about 15 feet above water level at the top of a low limestone ledge. There are several other small caves near by with their mouths along the same ledge. This cave is damp inside but there is little standing or running water in it. It was once used by the Indians as a dwelling place as well as a burial ground, and about a half mile from the mouth is a wide, flat rock that was used by the Indians for a table. Bats frequent this cave and in some places piles of guano have collected.

There are two main forks and each extends for nearly half a mile. There the loose earth is abundant. In some places it is as much as 6 feet thick but averages about 3 feet. The northwest fork averages 8 feet in width and 7 feet in height while the southeast one is somewhat wider and lower. In some places the cave is very narrow and sinuous

and the roof is very high and narrows to a mere crack. The stalactites and stalagmites are rather small but very numerous, especially in the northwest fork. In some places the walls are thickly studded with small knob-like projections of limestone about a fourth of an inch long. The southeast fork contains fewer stalactites but more loose earth.

No. 11. Haile Cave.

Location.—A fourth of a mile north of Flynns Lick, 40 yards south of No. 10 and at the same level in the Ordovician limestone.

The topography of the mouth of this cave is very similar to that of No. 10, being in a low, wooded limestone ledge with fields surrounding it above and below. The mouth is 10 feet by 6 feet, being a little larger than No. 10, and the floor slopes downward from the mouth at a little steeper angle, but the cave is not so large as No. 10. There is another mouth about 100 yards southwest of the main entrance that opens vertically into the cave from the top of the bluff and was formed probably by the caving of the roof. The front part of the cave is only slightly damp but near the back of it there is a stream of clear water.

The length of this cave is about 500 yards, while the width averages 15 feet and the height 6 feet. There are two low places through which it is necessary to crawl, one being near the vertical mouth and another farther back. There is a bat roost in this cave and considerable deposits of bat guano have been formed. The large numbers of bats flying about make it disagreeable to explore. The loose earth varies in depth at different places but it probably averages 3 feet. Indian remains have been found here, also. The stalactites and stalagmites are scarce and small.

No. 12. Fowler Cave.

Location.—Twelve miles southeast of Gainsboro on the farm of Dr. J. B. Fowler on the side of a steep hill or mountain half a mile southeast of Fowler's house, on the west side near the head of Fowler Hollow. It is about a half mile from a public road and 2 miles from the Cumberland River. It occurs near the junction of the St. Louis limestone and the Ft. Payne chert at the base of a limestone bluff 20 feet high.

The mouth is situated about two-thirds of the distance to the top of the hill in thick tangled woods and a large limestone boulder covers the northwest end of the mouth. The entrance proper is 6 feet wide and 5 feet high, but the width of the entire opening is probably 25 feet. The

floor slants downward from the mouth and except near the mouth it is extremely dry. There are some spacious chambers in the cave. It extends about 100 yards due south and then opens into a room fully 70 feet wide and 25 feet high, from which arms branch in various directions. The approximate length from the mouth to where the longest branch of the main room gets low is 300 yards, and it is said that one can penetrate farther by crawling a short distance. The average width is 25 feet and the height averages about 12 feet.

The loose earth averages probably 5 feet in the main part of the cave but certain thin strata are calcified so that it appears to be thinner than it is. Stalactites are scarce but the walls are worn away in a peculiarly grotesque manner in many places. It is a very attractive cave in spite of the scarcity of water formations.

No. 13. Van Hoover Cave.

Location.—On the farm of Ed Van Hoover, 4 miles northeast of Gainesboro, a half mile southwest of the Roaring River bridge and a fourth of a mile northwest of Van Hoover's house. It is only a fourth of a mile from a public road and a half mile from the Roaring River. It is located in St. Louis limestone about 10 feet above the Ft. Payne chert.

The mouth is in thick woods on the east side and near the top of a high hill. It slopes almost vertically downward for 25 feet and then the cave continues in a southwesterly direction for about 100 yards. It is rather small, being not quite 100 yards long and averaging 15 feet in width and 6 feet in height. The earth on the floor is damp but there is no water in this cave. The loose earth averages about 3 feet in thickness. There are very few stalactites or stalagmites.

No. 14. Saltpeter Cave.

Location.—At the head of Kirk Hollow 150 yards southeast of the Gainesboro-Celina road on the farm of Ormsby Kirk, 300 yards west of a small house. It is in Mississippian limestone, just above the Chattanooga black shale, at the foot of a dome-shaped overhanging limestone bluff 30 feet thick.

The mouth is situated in thin woods and is very picturesque. A stream flows from the cave, appearing as a spring 20 feet below the mouth. The mouth is funnel-shaped, and where narrowest is about 5 feet in diameter. It was not explored much farther than the mouth for

buzzards were using it as a nesting place. It is reported to extend westward for over 300 yards and to be quite large at places. Since water flows through the cave it is not likely to contain much saltpeter. The loose earth inside the mouth is about 1 foot thick.

No. 15. North Spivey Cave.

Location.—On the farm of Rad and Paul Spivey, a half mile northeast of Spivey's ferry, 2 miles southwest of Meagsville, in the north fork of Spivey's Hollow, 400 yards northeast of Tom Langford's house, near the top of the high bluff on the west side of Cumberland River. It is about a half mile from the public road and the same distance from the Cumberland River. It is located in Mississippian limestone about 10 feet above the top of the Chattanooga black shale.

The mouth is small and slit-like and slopes downward gradually for 100 feet. It is under an overhanging limestone bluff. The cave is quite dry and the earth on the floor at a short distance from the mouth is dusty. Its length is about a mile and its width averages 8 feet and height 10 feet. The cave is very sinuous and in places very narrow. There are some old steps about a half mile from the mouth. Lateral branches are numerous and confusing. The cave is said to open on the bluff of the Cumberland River over a mile from the mouth. It is also said that two men were overcome by foul air in this cave and one of them died.

The loose earth averages only 2 or 3 feet in depth, though in some places it is probably over 5 feet deep. The stalactites are quite numerous and beautiful and hang from the roof and cover the walls in places. There are also a few large stalagmites. It is reported that Indian implements have been carried out of this cave.

No. 16. West Spivey Cave.

Location.—On the farm of Rad and Paul Spivey on the west side of the Cumberland River, a half mile northeast of Spivey's Ferry, 2 miles southwest of Meagsville, 300 yards west of Tom Langford's house. It is about a half mile southwest of No. 15 and is in the west fork of Spivey Hollow, 50 feet below the top of the hill. It is a half mile from the Cumberland River and from a public road. It occurs 50 feet below the top of the hill in Mississippian limestone just above the Chattanooga black shale.

The mouth is at the base of an overhanging limestone bluff and is wide and low. Just within the mouth it narrows to 3 by 4 feet. It is only about 150 yards long, but its height averages at least 35 feet and its width 15 feet, while the main chamber is 65 feet high and 25 feet wide. The cave is quite damp but there is no permanent stream in it.

The cave earth averages about 5 feet in thickness and is a sticky yellow clay for the most part. The main roof is festooned on all sides with beautiful clusters of tapering stalactites and resembles in a striking manner the interior of a stately cathedral. The walls are very irregular and many grotesque shadow effects are produced in the dim lantern light. There are only a few small stalagmites.

No. 17. Cherry Cave.

Location.—On the farm of Bill Cherry, 3½ miles northeast of Meagsville on the west side of the Cumberland River, 100 yards west of Cherry's house. It is only 100 yards from a wagon road and a mile from the Cumberland River. It occurs in Ordovician limestone, 85 feet below the Chattanooga black shale.

The mouth is located near the base of a bluff in the middle of a clump of cedar trees. A stream flows through the cave for almost its entire length. The mouth is about 8 feet high and 9 feet wide and slopes downward for about 50 yards, where the stream is reached. This stream appears as a spring about 25 feet below the mouth. The cave is about 8 feet high and 6 feet wide, though in a few places it is low and wide. Its length is probably over a mile and it is very crooked. There are banks of loose earth that have been cut into by the stream to a depth of 6 feet in many places. Saltpeter is said to have been found here. The stalactites and stalagmites are very few and small.

MARION COUNTY.

No. 101. Saltpeter Cave.

Location.—Seven miles southeast of Monteagle on the land of J. H. Shetter at the foot of the mountain on the south side of Cave Cove, 100 yards from a small farmhouse. It is 6 miles from the Tracy City branch of the Nashville, Chattanooga & St. Louis Railway. It is in Mississippian limestone about 800 feet below the Lee sandstone.

There are two mouths about 200 yards apart. It is in the woods above the bed of a dry creek and near the edge of an old field and orchard. The cave is dry. The main part averages 30 or 40 feet in width

and 15 or 20 feet in height. There are a number of side passages, some of which are almost as large as the main cave, while others are very narrow. A white coat of gypsum incrusts practically all the walls. The cave is over 2 miles long and winds about very much. The earth averages 5 or 6 feet in thickness, though many banks are 15 feet or more. There are at least 25 or 30 old hoppers that were used in obtaining the niter from the earth. They are a little larger but similar to those in No. 53 and three or four tons of earth are heaped up in each of them. There are many evidences of digging. This earth is exceedingly dry and dusty like that in Big Bone Cave. There are no stalagmites or stalactites, but the walls and roof are very irregular in places. The passages are so numerous and intricate that it is very easy to get lost in them.

OVERTON COUNTY.

No. 39. Garret's Cave and Rock Shelter.

Location.—On the land of J. D. Garrett, 2½ miles west of Wirmingham, a half mile southeast of Garret's house. It is about 200 yards below a small road and a mile from the Livingston road. The nearest railroad is at Livingston, 9 miles away. It is in Mississippian limestone about 100 feet above the Chattanooga black shale. The cave is located at the head of a hollow through which a small stream flows and its mouth is at the back edge of a rock shelter. The middle of this rock shelter has fallen in, leaving the outside part of the roof standing as a small natural bridge. The gap between the roof of the rock shelter and that of the natural bridge is still only about 6 feet wide but is being enlarged by a small stream that flows down through it. The shelter is about 25 feet wide and 20 feet high and extends in an arc around the hollow for 300 yards. Where the stream flows over the edge it forms a pretty waterfall. The cave proper is small and rather low, extending about 100 yards back from the main mouth which is 5 feet high and 4½ feet wide. There are also several smaller mouths. There are two main rooms. The cave earth averages 5 feet or more in depth. Water floods parts of the cave at times. There are a number of short and thick stalactites near the walls that are quite pretty, but stalagmites are rare. It is reported that saltpeter was made in this cave about 1865.

No. 40. Saltpeter Cave.

Location.—On the land of W. R. White, 2 miles northwest of Monroe, a fourth of a mile southeast of White's house on the bluff of a small

stream near where it empties into Eagle Creek. It is a fourth of a mile from a wagon road and 6 miles from Livingston, which is a railroad terminus. It is in St. Louis limestone about 50 feet below the top of the bluff and 75 feet above the Ft. Payne chert.

The mouth is 6 feet high and 12 feet wide and is in rather thick woods under an overhanging bluff. There is a stream in the cave about 50 yards from the mouth, which extends to the back of the cave, but does not flow out through the mouth. This cave is 6 feet high and 7 feet wide and about 150 yards long. The earth on the floor averages 2 or 3 feet in depth and is found in banks mixed with rock fragments. Stalagmites and stalactites are few and small. The cave extends in a general southeasterly direction and there are no important branches.

No. 41. Wash Lee Cave.

Location.—Three miles northeast of Livingston on the farm of Wash Lee, 75 yards northeast of Lee's house at the head of Copeland Cove, at the foot of the mountain. It is 100 yards from the public road and 3 miles from the railroad. It is in St. Louis limestone, 300 feet below the Lee sandstone. The mouth is slit-like, being 50 feet wide and 5 feet high, and the cave extends downward at a rather steep angle. It is underneath an outcropping limestone cliff 20 feet high, in open pasture land, on the edge of thin woods. Cattle are housed in the cave in cold weather. Just inside the mouth the cave opens up into a main chamber which is tolerably well lighted from the mouth. This room is fully 75 feet high and 100 feet wide and is nearly circular in outline. Its roof is dome-shaped and the light which enters through the mouth gives it a greenish hue. At the inner edge of the main chamber a small stream falls from a rock 45 feet high and breaks into fine spray on the rocks beneath. The stream reverses its direction after falling over the precipice and flows away from the mouth. The cave branches in several directions and at several levels at the end of the main part, which is 150 yards long, but the roofs of these branches are too low to make exploration easy. The stream also divides like a river in a delta plain. The cave extends in a southeasterly direction and the floor is very uneven so that there are several more noisy waterfalls at intervals. There is a large amount of loose earth on the floor of this cave both in the main chamber and in banks in the back part. It will average probably 5 feet in depth. The average width of the back part of the cave is 35 feet and its height 20 feet. A few Indian arrowheads and some bones are found in the earth of the main chamber.

No. 42. Crawford Cave.

Location.—On the land of Bill Crawford, 3 miles southwest of Livingston, on the south side of the Overton County railroad, 20 feet from the track. It occurs in St. Louis limestone, 350 feet below the Lee sandstone.

The mouth is located in the railroad embankment about 20 feet above a rather large creek and is triangular in shape. It is about 8 feet wide at the base and 5 feet high in the center, and the cave floor slopes downward at a slight angle for a few feet inside the mouth. At a distance of 75 yards from the mouth a stream is reached which turns eastward and does not empty through the mouth on the railroad embankment. The cave averages only 4 feet in height from the mouth to where the stream is first reached, this part having been partly filled with earth. In the center, however, there is a very irregular, narrow cleft extending upward for an uncertain distance and in some places there are other rooms above this. After the stream is reached, the floor is lower so that the altitude is about 6 feet for the 150 yards from there to the other mouth which opens into a sink 30 feet deep. The average width of the whole cave is about 15 feet. The other mouth formed by the caving in of the roof, is larger than the first. The cave continues on the other side of the sink-hole but is quite narrow for a considerable distance. This cave probably connects with a larger cave about a mile away, called Bear Cave. There is much loose earth on the floor but it is flooded by high waters. The earth averages 4 feet in depth, but is much deeper near the first mouth. There are several very large, rounded stalagmites and in two places a group of short, thick natural columns that extend from the cleft in the roof to the floor. There are also a large number of smaller stalactites.

No. 43. Saltpeter Cave.

Location.—One and a half miles northeast of Windle on the land of I. F. Gregg, at the edge of a field a fourth of a mile southeast of Gregg's house. It is a fourth of a mile from a wagon road and 1½ miles from the railroad, and in St. Louis limestone about 50 feet below the top of a low hill.

The mouth is in low ground at the head of a small hollow and the floor slants downward slightly. It is on the edge of thin woods in the midst of a thick clump of bushes. It is 7 feet in diameter and nearly circular. There is a spring that starts 15 feet inside of the mouth and

flows toward the back of the cave. It is a half mile long and averages 10 feet in height and 8 feet in width. It is comparatively straight and there are no branches of any size. Near the back of the cave there are several large banks of loose earth 6 feet deep, but much of the earth has been removed. Holes have been dug in the earth and there are remains of what might have been a saltpeter hopper. It is reported that saltpeter was gotten from this cave during the Civil War. There are a few large stalagmites and some small stalactites present.

No. 44. Allen Cave.

Location.—A mile northwest of Windle on the farm of Monroe Allen on the edge of an old field a half mile southeast of Albert Qualls' house. It is in St. Louis limestone.

The mouth is located in the midst of a clump of bushes and brambles in an old field that is comparatively level. The mouth is 4 feet wide and 8 feet high. The earth is abundant and averages 4 or 5 feet in depth, but looks as if it has been recently flooded. It was quite damp inside but no stream was seen. It extends 300 yards to a place where it becomes low enough to make crawling necessary. It is about 6 feet high and 20 feet wide and seems to have been partly filled with earth recently. There are a few cave formations here.

No. 54. Saltpeter Cave.

Location.—Two miles northeast of Obey City, on the land of Billy Collins, in the bluff of East Fork of Obey River, 1½ miles from the Wilder branch of the Tennessee Central Railroad. It is in Mississippian limestone just beneath the Lee sandstone.

The mouth of the cave is 3½ feet high and 5 feet wide and is under a rock shelter which overhangs, and is 15 feet wide. The cave is about 100 yards long but is only 4 feet in height and 15 feet in width. There is a little earth in this cave. It is a hard yellow clay and is quite dry. In some places the earth is dark purplish red. The earth at the back of the cave is about 3 feet deep. The earth at the bottom of the rock shelter is very red and heavy. Bones, probably human, are found in the back of this cave.

No. 55. Quarles Cave.

Location—About a mile northwest of Green Pond on the land of Tilson Quarles in a hollow below, and a quarter of a mile north of

Wade Norrod's house, on the bank of Sourwood Branch, 100 yards west of the waterfall. It is in Mississippian limestone, 100 feet below the Lee sandstone.

The mouth, which is small and low, is under a small rock shelter in rather thick woods. It is necessary to crawl 60 feet before the first room is reached. This room is nearly cylindrical, its height being 40 feet and diameter 15 feet. It was probably formed by a stream down along a fissure or joint. There is another low place and then another comparatively large room. The cave, with the exception of these rooms, averages only 4 feet in height and 5 feet in width. There are gravel and some earth on the floor but it is flooded during rainy seasons, so there is little chance for niter. There are few stalactites and no stalagmites, but the walls of the rooms are gracefully carved by water.

No. 56. Quarles Rock Shelter.

Location.—A mile northwest of Green Pond on the land of Tilson Quarles under the waterfall of Sourwood Branch, 1¼ miles from Wade Norrod's house and three-fourths of a mile from the Wilder branch of the Tennessee Central Railroad. It is in Mississippian limestone, 100 feet below the Lee sandstone. It is 150 feet long, 15 feet wide and about 15 feet high. The earth on the floor is about 4 feet deep.

No. 57. Falling Water Cave.

Location.—One and a fourth miles northwest of Green Pond on the land of Tilson Quarles about 100 feet from the bottom of Big Sunk Cave, three-fourths of a mile north of Wade Norrod's house, and a mile from the Wilder branch of the Tennessee Central Railroad. It is in the St. Louis limestone about 500 feet below the Lee sandstone. The mouth is located in thick woods at the bottom of a rather large sink-hole 6 feet deep and about 200 feet wide. A stream flowing in a due easterly direction flows over the cliff above the mouth of the cave and forms a waterfall 40 feet high and then flows into the mouth of the cave in a due westerly direction. The mouth is 6 feet high and 12 feet wide. Just inside the mouth the cave is very large and the floor which slopes downward at a steep angle, is covered with large blocks of broken rock. The average width of the whole cave is 12 feet while the big room is 30 feet wide. During the recent high water the sink-holes in the bottom of the Big Sunk Cave were unable to accommodate all the water and it rose so high that it flooded the cave and filled it with

sediment for a fourth of a mile from the mouth. This cave is said to be over 2 miles long. There are banks of earth in it 6 feet thick that are not of recent deposition, though the average thickness of the earth is only 4 feet and much of this is sediment. The stalactites and stalagmites are rare but the walls and roof of the main room are curiously sculptured by solution.

No. 58. Pine Hill Rock Shelter.

Location.—One and a fourth miles west of Hanging Limb on the land of the Copeland heirs near the top of Pine Hill. It is 200 yards above a wagon road and a mile from the Tennessee Central Railroad. It is located where the Lee sandstone comes in contact with the Mississippian limestone.

It is very conspicuously situated and can be seen from nearly all the neighboring mountains. It is roughly rectangular in shape, being about 200 feet long, 20 feet wide and 25 feet high. It was worked considerably during the Civil War for saltpeter and the earth left is only 2 or 3 feet deep.

No. 59. Wolf Branch Cave and Rock Shelter.

Location.—Two and a half miles southeast of Hanging Limb on the land of the Briar Hill Collieries on the east bluff of Wolf Branch, a mile from the Wilder branch of the Tennessee Central Railroad. The cave is in Mississippian limestone, 50 feet below the Lee sandstone.

The mouth of the cave is at the back of a rock shelter 30 feet high, 20 feet wide and 200 yards long. The earth on the floor of this shelter is a foot deep. The cave is small and low and has a small stream running through it. Its average height is 4 feet and width 6 or 8 feet, and it is about 200 yards long, but becomes lower toward the back. The banks of earth are about 2 feet thick.

No. 60. Briar Hill Cave and Rock Shelter.

Location.—On the opposite side of Wolf Branch from No. 59. It is similar to No. 59 but a much larger stream of water flows out of it and there is a pretty waterfall in the mouth of the cave under the rock shelter. The shelter is not quite so large as that of No. 59.

No. 61. Quarles Cave.

Location.—On the land of Mrs. T. A. Quarles, 300 yards south of Quarles' house near the Three Forks of West Fork of Obey River, 4

miles west of Crawford. It is in St. Louis limestone, 400 feet below the Lee sandstone.

The mouth is 60 feet wide and 15 feet high and is in open woods 50 feet west of the county road in a slight sink at the head of a small ravine. For about 65 feet from the mouth the floor of the cave slants downward slightly but from that place back, there is a gradual upward slope that continues through the cave with the exception of sinks at various places along the floor. At the bottom of some of these sinks a stream can be seen. There is a small spring 60 feet inside the mouth whose water sinks into the ground. The cave earth averages 6 feet, while in places there are banks of loose earth mixed with angular rock fragments 15 or 20 feet high. There is no stream on the floor of this cave but one appears to flow underneath it. There are fragments of old shingles in one bank that may be the remains of old saltpeter hoppers and the earth seems to have been dug into in places. The cave is about 300 yards long, 35 feet wide and 20 feet high. There are a number of stalactites and some stalagmites.

No. 62. Peter Cave.

Location.—A fourth of a mile west of Rushing Springs schoolhouse, on the land of H. C. Kimes in an old field near the bottom of Dry Hollow. It is in St. Louis limestone about 500 feet below the Lee sandstone.

The mouth is in a small cane patch about 20 feet above the bottom of a sink in the valley. It is flooded by high waters and any niter present has probably been washed away. The mud on the floor is about 3 feet deep. The cave is 300 yards long and averages 12 feet in height and 8 feet in width. Its mouth is divided into two by a narrow natural bridge. It contains a few pretty stalagmites and stalactites.

PICKETT COUNTY.

No. 26. Phillips Cave.

Location.—Three miles southeast of Lillydale, 200 yards southeast of the signboard, "Byrdstown 10 miles". It is on the land of Jesse Phillips, 50 yards south, and in plain view of the road. It is in St. Louis limestone just above the Ft. Payne chert.

This is a small cave situated under a ledge of sandy limestone. It is open for about 50 feet and is then blocked by a large rock. The earth

on the floor is 4 feet thick and there are pools of water and a relatively large number of small stalactites.

No. 27. Pratt Cave.

Location.—Four miles southeast of Lillydale on the land of Jesse Phillips, 1200 yards southeast of Phillips' house in woodland about 50 feet below the top of the ridge. It is 400 yards from the Lillydale-Byrdstown road. It is in St. Louis limestone, 25 feet above the Ft. Payne chert.

The mouth is triangular, about 10 feet wide and 4 feet high and slopes downward for about 15 feet. It is a damp cave. There are a few pools of water but no stream in the main portion. There are a number of branches, some of which are 400 or 500 yards long, but they are narrow and there is practically no loose earth on the floor of them. The main part of the cave, which alone contains cave earth, is 100 yards long, 75 feet wide and 6 feet high in the center but only 3 feet or less at the sides.

There is a thick bed of dirt in this main portion. It is reported that it was worked for niter by one or two men for several years about 1890. The loose earth is from 5 to 7 or 8 feet deep. There are numerous stalactites and stalagmites formed against the wall and flattened at right angles to it.

No. 28. Harrison Cave.

Location.—On the farm of Mrs. Tom Harrison, 4 miles southeast of Lillydale, in thick woods a mile south of Mrs. Harrison's house, and three-quarters of a mile from the Byrdstown road. It was discovered by John Neal in 1915. It is in St. Louis limestone about 100 feet above the Fort Payne chert.

The mouth is a triangular hole and is very inconspicuous. It is located about 50 feet below the top of the hill, facing the mouth of Bone Cave, No. 29, and extends almost vertically downward for 12 feet. A little water drips from the roof of this cave but there is no stream or standing water in it. There are pockets and thin coatings of a white mineral that is possibly niter. The cave is about 75 yards long, 10 feet wide, and 15 feet high, and there is also a small branch nearly blocked by loose earth. The loose earth in this cave, probably averages over 5 feet in depth. It is possible to get to two more rooms by climbing over a bank 10 feet high. There are evidences that this cave was once used as a still. There are a few stalactites.

No. 29. Bone Cave.

Location.—On the farm of Mrs. Tom Harrison, 4 miles east-southeast of Lillydale, three-fourths of a mile south of Mrs. Harrison's house, a fourth of a mile south of No. 28 and in a similar situation. It is half a mile from the Byrdstown road.

The mouth is slit-like and only 2 feet in height and is in dense wood about 50 feet from the top of the hill. The present mouth was formerly walled up by the Indians and was discovered by accident. In the roof there is also a small opening. When this was covered over with snow a man lost his hunting boot in it. Through this opening a small boy was let down by a rope and he discovered rays of light entering where the present mouth is located. When the rocks blocking the mouth were removed and the light entered the cave, forty Indian skeletons were discovered lying on half decayed cane mattresses, hence the name Bone Cave. Just inside the mouth is a large round chamber at the back of which are two forks almost opposite each other which are each about 4 feet high, 6 feet wide and 50 yards long. The main chamber is 75 feet in diameter and 5½ feet high. The earth in the main chamber is probably 6 or 8 feet deep, for the bottom has never been reached, although much digging for Indian relics has been done. There are a few fringes of small stalactites hanging from the roof.

No. 30. Butram Rock Shelter.

Location.—On the land of Samuel Butram, 3 miles northwest of Byrdstown on Turkey Creek, a fourth of a mile west of J. L. Gunnel's house. It is beneath a hard layer of St. Louis limestone just above the Ft. Payne. The shelter is 150 yards long and averages 20 feet wide and 6 feet high. It is in the north bank of Turkey Creek 10 feet above water level, and extends in an elbow along the creek. The loose earth is 4 or 5 feet deep. It is about 400 yards from the public road. This shelter was used as a burial place by the Indians and eight or ten skeletons have been dug up here.

No. 31. Bear Cave.

Location.—On the land of James Dillon, 3½ miles northwest of Byrdstown, a half mile northeast of No. 30, down Turkey Creek, and about three-fourths of a mile from the public road. It is in St. Louis limestone, 100 feet above the Ft. Payne.

This cave has two mouths which connect about 100 feet from the outside. They are about 30 feet below the top of the bluff of Turkey Creek under an overhanging limestone ledge. The cave extends 100 feet in a southwesterly direction when it becomes so low that crawling is necessary to penetrate farther. The loose earth is at least 4 feet deep and farther back is probably deeper. It was once used as a hibernation place for bears. Small fragments of mica were picked up on the floor of the cave. In many places the earth is covered with a thin white coat, possibly of niter. Very little water drips from the roof and there are only a few small stalactites.

No. 32. Hood Cave.

Location.—On the land of the Hood heirs, 4 miles northwest of Byrdstown, a quarter of a mile east of Page Huddleston's house, at the head of a hollow that extends north to Wolf River. The public road is 400 yards south of the cave. It is in Mississippian limestone about 50 feet below the Lee sandstone. The mouth is about 100 feet wide and 5 feet high. It is located in thick woods about 25 feet below the top of Wolf River bluff. A stream flows through the cave, sinking into it about 300 yards south of the mouth near Huddleston Springs. The cave gets gradually smaller the farther one goes back and averages only about 3 feet in height and 6 feet in width. The earth is found mostly in the mouth and from it Indian skeletons have been dug up. There are very few limestone formations.

No. 33. Ice Cave.

Location.—On the land of the Hood heirs a half mile north of No. 32, a fourth of a mile east of John Hinsley's house in the thick woods 75 yards west of Rock Pinnacle and 500 yards from the road. It is in Mississippian limestone 30 feet below the Lee sandstone.

The mouth is near the center of a shallow bowl-shaped sink which was evidently formed by the caving in of the roof of the cave. It is peculiar in that it extends downward at an angle of 50 degrees away from Wolf River instead of toward it, although its mouth opens on the Wolf River bluff. Most of the cave is very narrow and its roof narrows upward into a fissure. This cave apparently is only the upper portion of a higher and more spacious cave that has been nearly filled up with fragments of rock. There must be another opening farther down on the Wolf River bluff. Near the mouth the cave is 12 feet high

and 20 feet wide, while the rest of it averages 3 feet wide and 8 feet high. Its length is about 50 yards. Water trickles from the roof, but does not form a stream. The cave is unusually cold, snow being found near the bottom still unmelted in July. There seems to be much earth on the floor though much of it is covered with rocks. Where seen near the bottom end the earth is 4 or 5 feet thick. The cave is practically straight so that the mouth can be seen from the end. There are many talagmites and stalactites near the walls of the cave.

No. 34. Groce Rock Shelter.

Location.—On the land of J. C. Groce, 5 miles northwest of Byrdstown in the bluff of Wolf River, a mile below the mouth of Turkey Creek on the south side of the river, a half mile south of the Kentucky line. The shelter is at the top of the bluff and is about 400 yards long, 135 feet high, and 15 feet wide. It is just above the Chattanooga black shale. The earth on the floor of the shelter is about 2½ feet deep and is mixed with fragments of black slaty shale. The earth itself seems to be almost pure saltpeter stained with a little bluish dust from the shale. There are large cakes of the pure white niter on ledges of rock, also, and several tons of this mineral could probably be obtained here.

No. 35. Phillips Cave.

Location.—On the land of Martin Phillips, 4 miles northwest of Byrdstown, a quarter of a mile north of A. A. Thompkins' house, at the head of a short ravine leading to Wolf River, 200 yards from a wagon road. It is in Mississippian limestone, 50 feet above the Chattanooga black shale. The mouth is wide and slit-like and it is reported that only a few years ago the stream that now appears much lower down, flowed out of this opening. This cave is 75 feet wide just inside the mouth but is only 4½ feet high and gradually becomes lower the farther one gets from the mouth. There is earth about 4½ feet deep mixed with angular rock fragments on both sides of the old stream bed. The roof is practically smooth and free from stalactites.

Nos. 36 and 37. Bunkum Cave.

Sample No. 36 was taken just inside the mouth while No. 37 was taken farther back.

Location.—At the head of a hollow 1½ miles east of Obey River, on the land of Irving Amlett, a half mile southeast of Bloomington,

and less than half a mile from the Byrdstown road. It is in Mississippian limestone about 100 feet above the Chattanooga black shale.

The mouth of this cave is probably larger than that of any other cave in the State and of course is correspondingly imposing. It is 150 feet wide and 65 feet high. A creek flows out of the cave and a small stream falls in a cascade from the thin ledge of limestone over the cave's mouth. The large stream flows through the entire length of the cave and forks several times. As many as 75 Indian skeletons and many relics have been dug up from the mouth of Bunkum Cave. The earth in the mouth is 10 or 15 feet deep and is mixed with large bowlders. This earth is quite dry and seems to contain much niter. There is also niter on the ledges projecting from the walls. There is a much larger quantity of earth in the mouth than there is farther back. The mouth is located in woods and the scenery surrounding it is quite wild. The main passage of this cave is 35 feet wide, 25 feet high and fully a mile long, and has a fork probably as long.

Most of the earth in the back of the cave has been worked over by the stream, and probably contains little niter. In many places there are wide ledges on which are beds of earth 2 or 3 feet thick which contain gypsum crystals, and in places a thin coat of white gypsum is found on the rocks. Toward the upper end of the cave there are many large, beautiful, and bizarre stalagmites, stalactites, and columns, some of which are pure white. The east fork of this cave contains a remarkable series of water-formed calcite terraces that extend for over a hundred yards in length while the vertical distance from the top to the bottom of the series is about 40 feet. Each terrace averages about 8 inches in height and forms a series of arcs or semi-circles that are themselves indented into smaller arcs in a peculiar manner. The top of each step or terrace is a shallow basin filled with the clearest and stillest water imaginable. The rims of these pools vary from an eighth of an inch to a foot in thickness and have been built up by the water which trickles over them in a thin sheet. Some of the pools in the basin-like depressions on the top of the terrace are 4 feet deep and the water is so clear that they seem empty. An old still was once located in the mouth of this cave and the name Bunkum originated from applying this term to the still.

Babbs Rock Shelter.

Location.—On W. J. Babbs' land on the north bluff of Wolf River a mile above Groce Shelter, a fourth of a mile north of John Gunnel's

house. It is about the same size and similar to Groce Rock Shelter and probably contains considerable niter.

Woods Rock Shelter.

Location.—Two miles north of Byrdstown on the Albany road, 200 yards above Haile Ford in the Wolf River bluff. It is over 100 yards long. It contains Indian relics and is said to contain a quantity of niter. Two small caves extend into the bluff here also.

No. 37. Paris Rock Shelter.

Location.—On the land of Ross Paris, in the top of the Obey River bluff 5 miles west of Byrdstown, 300 yards from Philip Garrett's house. It is 400 yards long and averages 40 feet in height and 15 feet in width. The loose earth is 6 or 8 feet deep. Many Indian skeletons with fine wampum beads have been unearthed here, one having with it over a thousand such beads.

No. 38. Keislin Rock Shelter.

Location—On the land of Albert Keislin on the northeast bluff of Obey River, 5 miles west of Byrdstown a half mile north of No. 37. The shelter is 500 yards long and averages 25 feet high and 20 feet wide. There is considerable crust of almost pure niter on the earth and the earth, which is about 3 feet deep, seems to be impregnated also. According to reports there are many similar rock shelters on Wolf and Obey rivers that are said also to contain quantities of niter.

PUTNAM COUNTY.

No. 51. Milligan Cave.

Location.—Three-fourths of a mile north of Dug Hill on the land of Joe E. Milligan about half way to the top of the mountain, a fourth of a mile east of Doc Cobb's house, 12 miles south of Monterey and a half mile from the Calfkiller River. It is a fourth of a mile from the Sparta-Monterey road and 4 miles from the Nashville, Chattanooga and St. Louis Railway at Ravenscroft. It is in Mississippian limestone, 50 feet below the Lee sandstone.

The mouth is located at the base of a small sink-hole in the woodland and is about 20 feet wide and 7 feet high. The cave extends almost due south for 600 yards, and then turns east for about a quarter of a

mile before it becomes too low to penetrate farther without stooping. The average width is 50 feet and the height 20 or 25 feet. It is slightly damp just inside the mouth, but throughout most of the cave it is dry and dusty. There is much loose earth just inside the mouth where the cave is largest and the old hoppers where saltpeter was extracted from the earth during the Civil War are fairly well preserved. In the back part of the cave the loose earth is apparently 6 or 7 feet thick. Pick marks show that it was once worked back there. The middle part of the cave is over half filled with loose rocks, some of which are very large.

No. 52. JOHNSON CAVE.

Location.—Eight miles south of Monterey on the Sparta-Monterey pike, on the land of Lewis D. Johnson, a fourth of a mile southwest of Johnson's store, about half way up the mountain. The mouth is 500 yards up the mountain from the Sparta-Monterey road and 5 miles from the Nashville, Chattanooga and St. Louis Railway at Ravenscroft, but the Tennessee Central at Monterey is probably more accessible. It is in Mississippian limestone about 75 feet below the Lee sandstone.

The mouth is 8 feet in diameter and opens downward at an angle of about 75 degrees for 75 feet. It is in an open wooded pasture on the northeast side of the mountain. There is an old ladder about 80 feet long in the mouth. At the bottom and a little southwest of the mouth is a great dome-shaped chamber fully 200 feet wide, 300 feet long and 75 feet high. One small and three large forks extend in various directions from the main chamber. One of these averages 30 feet high and 25 feet wide for probably a mile. The writer explored this fork for about a mile. It is said to extend over two miles but nobody has ever been to the end of it, as there is great danger of getting lost owing to the number of side passages leading in all directions. There are several passages above the main cave.

Another large fork 20 feet high and 25 feet wide also extends for a mile or more. It is very rough in places and the floor rises and falls many times. It is said that men have walked for fourteen hours in this cave. It was worked during the Civil War for niter and remains of large hoppers may still be seen, while holes 15 or 20 feet deep have been dug in the main room. There are also great banks of earth along both of the larger forks as well as in the main chamber. The earth probably averages 4 feet in depth for the whole cave, although it is difficult to estimate this. It is damp in the main chamber, but in the

forks it is almost dry. There are a number of short, thick stalacties and stalagmites and some terraces in the main cave. The roof and walls, especially of the main chamber, have been elaborately carved by water.

No. 53. SALTPETER CAVE.

Location.—Seven miles south of Monterey on the land of Lewis D. Johnson, a mile northwest of Johnson's store and a mile west of No. 52 on the opposite side of the mountain a little nearer to the top. It is about a half mile from the Sparta-Monterey pike. It is in Mississippian limestone about 35 feet below the Lee sandstone.

The mouth is at the head of a cove in second growth woods, and is an irregular opening 100 feet long and 25 feet wide and extends vertically downward for 75 feet. It is possible to climb down over the irregular ledges of rock with the aid of a long smooth pole near the bottom. Just inside the mouth is a very large chamber, 250 feet wide and 100 feet high. Broken rocks are piled up all over the floor of this chamber. From the main room the cave extends southwest for only a quarter of a mile before it becomes too low to penetrate much farther. Excepting the main chamber, the average width is 60 feet and the height 15 feet. There are no formations in this cave.

The loose earth was originally 15 feet deep or more, but much has been removed though there are high banks of it at the back of the cave with the marks of picks plainly visible. Many workers were employed in this cave during the Civil War and it was worked much more than No. 52.

The old hoppers, troughs, and barrels, where the niter was leached out of the earth are in an excellent state of preservation and are still full of the hard, yellow clay which contained the niter. The hoppers in this cave are typical of those in most caves in this region. They are rectangular and about 10 by 6 feet at the top. The sides slope gradually together and at the bottom are about 4 feet wide. They were about 5 feet high and in shape somewhat resembled a very wide and deep, flat-bottomed boat. The bottoms are made of broad, flat boards which are laid across small logs that raise it a short distance from the ground. Under them wide V-shaped troughs or hollowed-out logs were placed to receive the water that filtered through the earth in the hopper. The sides of most of the hoppers are made of long hewn shingles with one layer overlapping the other as on the roof of a house. In some cases boards are nailed on the outside of these shingles to make the hopper stronger. These hoppers are very crudely made and probably the

earth which has been leached still contains some niter. There were also fragments of iron kettles where the water containing niter was boiled down and barrels in which water was probably kept. Some of the wood is fairly well preserved while other pieces, although dry, can be crumbled between the fingers easily. These hoppers vary somewhat in different caves but the great majority are as described above.

No. 63. Bilbrey Cave.

Location.—Two and a half miles south of Booze P. O. on the land of Joe Bilbrey, 300 yards northwest of a small log schoolhouse and a mile north of Beaver Hill. It is in St. Louis limestone.

The mouth is in the low east bluff of a branch a few hundred yards west of the public road in cut-over woodland. It is 5½ feet high and 3½ feet wide. This cave is damp and has a small stream flowing through it. It is narrow and sinuous and has but little loose earth and but few stalactites. There was once a whisky still in it.

No. 64. Webb Cave.

Location.—A mile west of Beaver Hill on the land of J. C. Webb, 50 yards below Webb's house. This cave is about 60 yards from the wagon road and 4 miles north of the Tennessee Central Railroad. It is in St. Louis limestone about 250 feet below the Lee sandstone.

The mouth is about 30 feet wide and 5 feet high and has a spring in it. The average height is 4½ feet and it gradually becomes lower toward the back. The width is about 25 feet, while the length is about 150 yards. The earth averages about 5 feet in depth. It is said that niter was mined here at one time. About 15 feet back of the mouth the earth is dry and dusty. There are holes in the floor through which a stream may be seen about 15 feet below. The roof is smooth and even.

No. 65. Saltpeter Cave.

Location.—Two miles southwest of Beaver Hill, 7 miles northeast of Brotherton, on the land of A. Q. Qualls, 400 yards east of Qualls' house and store. It is in Mississippian limestone about 150 feet below the Lee sandstone.

The mouth is located in a sink-hole in an old field. The sink-hole is about 20 feet deep and 60 feet in diameter and is thickly overgrown by tulip tree suplings. The mouth slants downward for 20 feet and continues in a northerly direction for 400 yards. There is a stream at

the back of the cave but the main part is almost dry. The average height is 20 feet and the width 30 feet. There are several holes in the floor through which a stream may be heard some distance below. Some years ago a whisky still was located here. There are banks of loose earth along both sides of the cave which average 3 or 4 feet in depth. Holes have been dug in this earth and it is said that niter was once mined here. There are several rather attractive stalagmites and a few stalactites along the walls of the cave and a few stalagmites on the floor.

No. 66. Ealy Cave.

Location.—Three miles north of Bilbrey Station on the land of O. A. Kirby, 500 yards south of Curtis Looper's house below his apple orchard. It is 2½ miles from the Tennessee Central Railroad, and a fourth of a mile from the public road. It is in St. Louis limestone.

The mouth is under a rock shelter of sandstone 25 feet high and 30 feet wide. It is in the woods near a dim road and there is a sinkhole 20 feet deep in front of the mouth. The mouth of the cave is about the middle of the rock shelter and is 8 feet high and 12 feet wide. The cave proper is small and the roof becomes only 3½ or 4 feet high 50 yards inside the mouth. The average width is 10 feet. The earth in the mouth is quite dry but that in the cave is wet and there is a small stream present. That in the mouth has been dug up and removed for a depth of 8 feet and ashes are mixed with it for a depth of at least 5 feet. This cave is noted because a man named Ealy hired hands and dug there for over a year until his money finally gave out. A woman then financed further digging but they never seemed to find what they were looking for. Soon after the man died. His body was placed in this cave at his request and the inhabitants of this region are very superstitious about it. It is said they were hunting for buried treasure which was supposed to have been hidden here by Indians. Many skeletons and trinkets were removed from the cave during the process of digging. There are no formations in this small cave.

SMITH COUNTY.

No. 1. Hughes Cave.

Location.—A mile south of Carthage in the west bluff of Cumberland River, 200 feet above the river and 200 yards north of the mouth of Caney Fork. There is a wagon road 100 feet below the mouth. This cave is in Ordovician limestone, 100 feet below the top of the bluff.

The mouth of the cave is 25 feet high and 20 feet wide and is very conspicuous in the bare limestone bluff.

About 50 feet from the mouth a peculiar thin ledge of limestone extends across the center of the cave about half way between the roof and floor. It varies from 8 inches to 2 feet in thickness. The cave is 150 yards long and averages 12 feet wide and 15 feet high. The floor slopes upward from the mouth at an average angle of 10 or 15 degrees.

The loose earth averages about 2 feet in depth and is mixed with fragments of limestone. There are a few small stalagmites and stalactites. Most of the stalactites are in rows on the edges of ledges that project from the walls of the cave though a few also hang from the roof. The cave is slightly damp though there is no stream in it. The loose earth is practically dry.

No. 2. Lee Cave.

Location.—In the southeast bluff of the Cumberland River 2½ miles southeast of Carthage, 150 feet above the level of the river and two-thirds of the distance to the top of the bluff, on the land of Mrs. S. B. Lee. It is a half mile from a wagon road and is between Cumberland River and Caney Fork, a mile southeast of the mouth of the latter. It is in Ordovician limestone.

The mouth is small and quite difficult to locate, being only 4 feet wide and 2 feet high. It is located at the top of a steep bluff in rather dense woods and near it there are a few cedar trees. The cave extends downward at a slight angle for 20 feet and then continues level.

There is no stream in the cave but it is quite damp inside. The main part of this cave is 150 yards long, 8 or 10 feet high and 15 feet wide and extends in an easterly direction, though there are many crooks and turns in it. The loose earth on the floor averages 3½ feet in depth and extends throughout the length of the cave. Many bones of Indians have been dug up from this earth. It is damp on the surface but becomes dry a few inches below the surface. There are very few stalactites or stalagmites. Most of the stalactites once there have been broken off. Near the end of the cave there is a stalagmite mass 8 or 10 feet long that resembles a frozen cascade.

No. 3. Piper Cave.

Location.—A mile west of Monoville on the farm of Jim Phillips, 100 yards south of Phillips' house. The mouth is about a half mile from a public road and easily accessible to the Tennessee Central Rail-

road at Carthage and the Cumberland River which is only about 2 miles from the cave at places. It occurs in Ordovician limestone about 50 feet above the Cumberland River.

The mouth of the cave is 6 feet high and 8 feet wide and is near the bottom of a small depression in a pasture. There is a rude wooden gate in the mouth.

A little water drips from the roof and forms pools but there is no regular stream in the cave. This cave is very large. It has two large and several smaller forks. The cave forks a quarter of a mile from the mouth. The northwest fork is the longest. It is definitely known to extend for 2 miles when it narrows to a small hole through which it is necessary to crawl in order to penetrate farther. This fork is said to extend another mile to the bluff of the Cumberland River. The south fork is a mile long and is damper than the northwest fork. In both forks there are numerous old hoppers that were used for making niter during the Civil War times. These are still in a fair state of preservation. Considerable quantities of saltpeter were mined by Jos. Piper who used to live near the entrance of the cave. However, a large amount of earth containing niter apparently still remains and clear crystals of niter can be found between rocks on the floor of the cave. The average thickness of loose earth is 5 or 6 feet though in many places it is as much as 10 feet. This appears to be one of the best prospects in the State for niter caves. The width of the cave is 35 feet and height 20 feet. There are a few large and beautiful stalagmites in it, but stalactites are rare.

No. 4. Buzzard Cave.

Location.—Two and a half miles west of Monoville on the west side of Cumberland River on the farm of Wm. Hull under an overhanging limestone cliff half way up the bluff. The mouth is 4 feet high and 6 feet wide and extends upward into a chamber whose size was not ascertained since the cave was being used as a breeding place by buzzards. The mouth is dry, and the loose material just inside is 3 feet deep.

No. 5. Hull Cave.

Location.—Two and a half miles west of Monoville on the farm of Wm. Hull, three-fourths of a mile north of Hull's house at the base of an overhanging cliff on the Cumberland River bluff. The cave is very convenient to the river but is rather inaccessible to the public road a half mile south of it. This cave has probably never been explored be-

fore and was penetrated only a half mile, though it extends farther. It is in Ordovician limestone, 60 feet above the river level.

The mouth is 5 feet high and 20 feet wide. The bluff in which it occurs is densely wooded wherever there is soil.

The cave extends eastward and has two main forks and several small ones. The longest fork turns abruptly northeast about 100 yards from the mouth while the other continues eastward for half a mile or more. The average height is 6 or 7 feet and the average width 6 feet. It is very nearly dry inside and there is no standing or running water in it. There is much loose earth on the floor, especially of the north fork. Its average depth is probably 6 feet. There are but few stalagmites or stalactites, and these are mostly near the walls. There are a few columns.

No. 6. Bridgewater Cave.

Location.—Two and a half miles northwest of Monoville in open pasture belonging to Mark Bridgewater, on a hill slope facing east toward the creek, 200 yards west-southwest of Bridgewater's house. This cave is 300 yards from Pleasant Shade road, about a mile from Cumberland River, and is easily accessible. It is in Ordovician limestone.

The mouth is about two-thirds of the distance to the top of the hill and is covered with poles and surrounded by weeds so that it is hard to find. It extends downward for 30 feet and then westward. Its dimensions are 5 by 4 feet.

The interior of the cave is damp but there are only a few puddles of standing water in it. The average height of the cave is 8 feet, though it varies considerably from place to place, and the average width is 25 feet. The cave can be penetrated only about 300 yards without crawling, when the passage becomes blocked by earth. The loose earth probably averages 6 feet in depth. Much was removed for niter during the Civil War and there are still many evidences of digging. The leaching hoppers were located outside of the cave. Needle-like crystals, some of which are half an inch long, glisten in the sticky yellow earth. Stalactites and stalagmites are abundant and beautiful and form fantastic patterns. Of the two the stalactites are the most prominent and most of them are unbroken. Some are 2 feet thick at their base. In many places columns have been formed. Most of these formations are about 250 yards from the mouth. There is an ash heap 6 feet high and 15 feet in diameter about 200 yards back from the mouth.

No. 7. Piper's Cave.

Location.—One and a half miles south of Difficult, a mile south of T. T. Kemp's store on the farm of Clare Piper, 300 yards southeast of Piper's house. It is in Ordovician limestone half way up a high hill.

The mouth is rectangular, 5 by 8 feet in size, and slopes downward steeply for 15 feet. The cave is damp inside but there is little or no standing or running water. This is a very beautiful cave with its fantastic formations. The longest fork extends about 400 yards before it becomes too low and narrow to penetrate easily. There are many passages several of which open back and forth into each other. The floor is very uneven. There are many steep grades and rough places and several small holes through which it is necessary to crawl. The average height is probably 10 feet though it varies greatly. The width also varies, but averages about 8 feet. There is no loose earth except near the mouth where it is 5 feet thick. It extends back 75 feet on the south side of the mouth.

The stalactites and stalagmites are very abundant and beautifully varied in size and shape. In many places the walls are covered with mushroom-shaped deposits an inch or less in length. In many places the stalactites and stalagmites have united and formed columns of various sizes and shapes. Many stalagmites form large, cone-shaped bodies.

No. 8. Ladd Cave.

Location. — A half mile south of Difficult at the base of the east bluff of Defeated Creek, 200 yards south of W. F. Ladd's house on the land belonging to Ladd. The mouth is only 50 yards from the public road and about 20 miles from the Carthage Branch of the Tennessee Central Railroad. It is in Ordovician limestone.

The mouth is only 3 feet by 5 feet and the average height of the roof for 100 yards is only 3 feet. Farther back it becomes much wider and higher, but is difficult to penetrate. The average width of the front part is 6 feet and it becomes about twice as great farther back. There are said to be some large rooms about 200 yards from the mouth.

The loose earth in the cave is very thick but is probably flooded at times by high water. The average thickness is about 5 feet or possibly more. It is reported that Dr. Kemp of Difficult analyzed earth from this cave and found niter.

No. 67. Little Petty Cave.

Location.—Two and a half miles north of Lancaster on the land of S. A. Petty on the southeast bluff of Caney Fork, 50 feet above the river, 200 yards east of Petty's house. The Tennessee Central Railroad is about a mile to the east. It is in Ordovician limestone, 75 feet below the Ft. Payne chert. There is a wooden door in the mouth and it is used for storing farm products. The mouth is under a rock shelter 10 feet wide and 40 feet long. The cave is small, there being three forks that extend about 100 feet each.

The earth is a foot deep in the rock shelter and 3 feet in the cave. There are a few cone-shaped stalactites.

No. 68. Big Petty Cave.

Location.—A hundred yards east of No. 67 on the same side of the river and in a similar situation.

The mouth is the most imposing part of this cave. It is 50 feet high, and 30 feet wide, and is roughly oval-shaped. It is cut out of the Caney Fork limestone bluff, which is almost perpendicular and 100 feet high. The cave is 200 yards long and is roughly funnel-shaped, being largest at the mouth. It is very straight, so that the light of the mouth can be seen at the back of the cave. The floor slopes upward gradually from the river and a small stream flows along it and sinks near the mouth. There is very little earth on the floor. The roof and walls are practically smooth.

No. 69. Rip Van Winkle Cave.

Location.—One and a half miles north of Sebowisha, near the top of the bluff on the opposite side of Caney Fork from Sebowisha Club House, on the land of W. M. Bellar.

The mouth is only about a mile from the Tennessee Central Railroad and is on the Caney Fork River, which is navigable up to this point. It is in Ordovician limestone, 30 feet below the Ft. Payne chert.

The bluff in which the cave is located is almost perpendicular and is wooded below the mouth of the cave. Above the mouth is an overhanging limestone bluff 30 feet high. When it was first discovered on February 1, 1916, by Harry Fisher, the mouth was very small and low, but it has since been enlarged so that entrance is easy.

The cave is very large and has two main forks. The southeast, or Dry Fork, is about a third of a mile long, while the northwest, or Wet Fork, is over half a mile long. There are also several smaller forks,

especially on the Dry Fork, and at places there are other passages above the main ones. The average width is 40 feet and the height 75 or 100 feet. In the Wet Fork several bridges and flights of stairs have been built and many improvements made to accommodate tourists to whom the cave is open at certain times. Near the back of the Wet Fork is a small stream and the earth, which is heaped up in banks is wet. The earth in the Dry Fork is peculiarly dry and contains a great abundance of transparent crystals of gypsum. These gypsum crystals, some of large size, cover the walls and the stalactites and stalagmites with a coat of sparkling gems. The depth of the earth could not be determined accurately but it averages probably over 6 feet, and in places is as much as 20 feet deep.

This cave is the most beautiful of the 109 caves visited, even somewhat surpassing Wonder Cave near Monteagle. It does not contain as many stalactites, stalagmites and natural columns as Wonder Cave, but they are much larger and more varied than those of Wonder Cave. The roof is also very much higher and more fantastic. The limestone formations are abundant in both forks, but probably the most interesting are in the Wet Fork. There is one especially beautiful group of stalactites called the Wedding Bells that is 60 feet long and 25 feet in diameter at the center. These stalactites are of all sizes and when struck, give forth musical sounds resembling a pipe organ and ranging from the highest treble to the deepest bass. Most of them seem to be hollow. There are other stalactites and columns that are even longer and larger than the Wedding Bells.

Near the end of the Dry Fork there are many shallow basins separated from each other by very thin, wavy partitions of limestone about 10 inches high that have been built up by the water with which they are filled in winter. In the bottoms of these basins was a deposit of loose crystals resembling salt 3 or 4 inches deep. The odd basin-like formations are not peculiar to this cave but the knife-edge partitions here are unusually high. In most caves in which these basins are found they are filled with such clear water that they appear to be empty. There are in this cave, also, many beautiful dome-shaped and waterfall-shaped stalagmites, some of dazzling whiteness.

No. 70. Prichard Cave.

Location.—Three miles southwest of Lancaster on the land of John Prichard, on the east bluff of Smith Fork, a quarter of a mile up the

creek from Dee Driver's house. It is in Ordovician limestone, 75 feet above the level of Smith Fork.

It is a small cave with two rooms. The mouth is in a steep bluff overlooking and in sight of, the public road. It is dry and the earth is 2 or 3 feet deep. The cave is about 100 yards long, 10 feet wide and 5½ feet high. There are a few stalactites and stalagmites.

No. 71. Fisher Cave.

Location.—Three miles southwest of Lancaster on the land of John B. Fisher in the west bluff of Smith Fork, about 100 yards northwest of the creek and 300 yards south of Fisher's house. The mouth is 150 yards from the Temperance Hall road, and 2½ miles from the Tennessee Central Railroad. It is in Ordovician limestone about 60 feet below the Ft. Payne.

This cave has two mouths about 40 feet apart. The main cave is over a mile long and has a fork extending southeastward for 300 yards that is much wider than the main fork. The average width of the cave is 15 feet but it varies very greatly at different points. The height is 25 feet. There is no stream in the southeast fork and none in the southwest, or main fork, for more than half a mile, but the earth is damp. Bowlders and rocks practically block the passage in the main fork in places. The loose earth is about 5 feet deep. There are a few stalactites near the mouth of the cave and about half a mile from the mouth there are several large stalagmites, but these formations are for the most part lacking. A strong breeze blows through the cave, and makes it quite cold in summer.

VAN BUREN COUNTY.

No. 83. West McElroy Cave.

Location.—Two miles southeast of Quebeck, 450 yards southwest of McElroy, on the land of Mrs. E. H. McElroy, 350 yards southwest of her house. It is in St. Louis limestone, 25 feet above the Ft. Payne.

The mouth is in a small sink in the woods about 50 yards from the edge of a field. It is 5 feet high and 15 feet wide and slants downward from the outside. The cave extends 400 yards almost due south and consists mainly of two large rooms with a narrow place and a high pile of earth between them. The average width for the main part is fully 50 feet and the height 25 feet. By crawling through narrow and low places it is possible to penetrate some distance beyond this main part.

The earth in the main part of the cave averages 10 feet deep, probably. This earth has been extensively dug and old inhabitants say it was carried to a nearby spring and leached for niter. There are some very beautiful stalagmites and stalactites but many have been broken off. The cave is nearly dry.

No. 84. North McElroy Cave.

Location.—Two and a half miles southeast of Quebeck, three-fourths of a mile south of McElroy, on the farm of Mrs. E. H. McElroy. It is half a mile from the public road and 2½ miles from the Nashville, Chattanooga and St. Louis Railway at Quebeck. It is in St. Louis limestone, 200 feet above the Ft. Payne.

The mouth is on the top of a small mountain south of McElroy's store in rather thin woods near an old house. It is in a sink-hole about 100 feet in diameter and overgrown with trees. The mouth is 5 feet high and 6 feet wide. The cave is damp but there is no permanent stream in it. There are four or five branches extending in various directions from a large room which is divided into three parts by walls of limestone. The length of the cave is about 250 yards and two of the branches are of about the same length. The average width is about 8 feet and the height is about the same. The loose earth averages 2 or 3 feet. There are few formations.

No. 85. South McElroy Cave.

Location.—Twenty-five yards south of No. 84, and in a similar location.

The mouth is 8 feet square. About 30 feet south of the mouth a dark hole or chasm fully 60 feet wide extends vertically down so far that a rock takes several seconds to hit the bottom. The cave extends westward about 50 yards. There is probably a much larger cave at the bottom of the chasm. Water can be heard at the bottom of the large hole. The cave is 30 feet wide and 15 feet high. The loose earth is scanty and there are only a few small stalactites.

No. 86. Big Bone Cave (Arch Cave Branch).

Location.—Three and a quarter miles south of Quebeck, near the head of a hollow or cove extending south from McElroy's store. The mouth is half a mile from the public road and 3 miles from the Sparta

branch of the Nashville, Chattanooga and St. Louis Railway. It is in St. Louis limestone, 50 feet above the Ft. Payne chert.

The mouth is in open woods near the base of the mountain and near the head of the hollow. About 50 yards in front of the mouth is a wooden shed in which bat guano was stored. A tramway extends about 400 yards into the cave and enters the southwest or Arch Cave branch. It was used for hauling out bat guano which is found in considerable quantity in one part of the cave. Over a carload of this fertilizer has been shipped from Quebeck. Work, however, has now stopped. The mouth of this cave is 20 feet wide and 8 feet high. About 50 yards inside the mouth the cave divides into two branches, the southwest or Arch Cave Branch and the south or Bone Cave Branch. Both caves are very large, though the Bone Cave Branch is the longer and larger of the two. The Arch Cave is about 1½ miles long, is very sinuous and branches many times. The branches extend in various directions and some rejoin the main passage. About a half mile from the mouth is a round hole 4 feet in diameter, which is called the needle's eye, and somewhat farther is a broad level place called the muster ground. The floor of this branch is everywhere of earth and is surprisingly smooth. The average width of this branch is 7 feet and the height 8 feet. The cave is very dry and dusty. In several places as much as half of the earth on the floor consists of long, fibrous or needle-like crystals of gypsum. In other places the upper layer of the earth is coated with white powder as much as 2 inches thick. This is also found in lumps mixed with the earth. The earth is certainly 5 feet deep and probably more. This cave is very famous, and this branch, especially, has been visited frequently by people from all parts of the United States. This cave is peculiar in containing no stalactites or stalagmites.

No. 87. Big Bone Cave (Bone Cave Branch).

Location.—Same as No. 86. This is the south or southeast branch of this same cave.

It is larger than No. 86, but is very much rougher and full of broken rocks in places. It is said that nobody has ever been to the end of this branch, though it is known to extend 3 miles. The writer explored it for about a mile. The average width is 15 feet and the height 20 feet. It is dusty and dry except for about the first 100 yards, where the earth is muddy from water that has flowed in through the mouth.

Much work must have been done in this cave in Civil War times, for there are more than twenty hoppers each 20 feet long, 12 feet wide at

the top, and 10 feet high, constructed with shingles as described in No. 53. The logs on which the hoppers rest are laid across a ledge on the walls of the cave and are raised about 5 feet above the present floor, which was probably lowered by the removal of earth. There are several ladders, a tramway and some scaffolding across another ledge above the hoppers with a network of beams and boards above them. These timbers are in an almost perfect state of preservation, while the timbers in most caves may be crumbled between the fingers even though they appear to be sound. There are several tons of dry, yellow, clayey earth, in each of the hoppers. It is thought that there is more niter in this cave than in Arch Cave, though more evidences of it, or rather of nitrocalcite, were found in the other branch. While much of the earth has been removed already, yet it is still at least 4 feet deep, but has large, flat limestone slabs mixed with it. In some places the earth is sandy. This branch extends south and then south-southeast and curves less than the other branch. There are no forks wide enough to penetrate far, and no stalactites or stalagmites. At one place the cave is nearly stopped up by sandy limestone that has fallen from the roof, and there are several rather low places. This branch has a very peculiar odor. There was no evidences of any soda in this cave. A few bats, as well as numerous rats, live in this branch at present. This cave was called Bone Cave because the skeleton or a large prehistoric animal, the Megalonyx, was found in it some years ago, together with other bones.

WARREN COUNTY.

No. 104. HUBBARD (BAT) CAVE.

Location.—Four miles southeast of Irving College, 8 miles north of Beersheba Springs on the land of J. S. Coppinger, a mile north of L. V. Scott's house, at the forks of the cove extending northeast from Scott's house. This cave is half a mile from the public road and 9 miles from the Sparta Branch of the Nashville, Chattanooga and St. Louis Railway at McMinnville. It is in St. Louis limestone, 500 feet below the Lee sandstone.

The mouth is a vertical opening about 70 feet in diameter and 30 feet deep. At the bottom of this large opening there are three passages, one extending north, one south, and a small one west. The west passage is extremely sinuous and in many places very narrow, but finally leads into a large cave that is probably 3 miles long with an aggregate length of all of its passages probably 6 or 8 miles. Some of these pas-

sages are high above the main cave and are reached by ladders. The north passage also finally leads into the largest part of the cave, although it is rougher and less direct. The south passage extends only about half a mile. There is a large saltpeter hopper in it near the mouth. The average width of the main part of the cave is 50 feet and the height is at least 60 feet with places above it much higher. The cave gradually gets narrower toward the top. Practically the whole cave is dry and dusty and probably contains much niter mixed with the earth. Some of this earth has been taken out by the forest nurserymen in this region and used as fertilizer. It is said to be excellent for this purpose. Needle-like crystals of gypsum cover the walls in thick coats and are mixed with the loose earth. They sparkle like gems on the walls and floor. The average depth of the earth is fully 10 feet, while in several places there are banks 30 feet high. This cave is even larger than the famous Big Bone Cave and comparatively little of the earth has been removed. The cave is very rough and there are several ladders, stairways and bridges.

No. 105. Woodley Cave.

Location.—This is a large cave near the head of Northcut's Cove, 8 miles southwest of Altamont, Grundy County. It contains many hoppers used in Civil War times, and much powder is said to have been made here. Indian skeletons were dug up in this cave. It was not visited by the writer.

No. 106. Rogers Cave.

Location.—Three and a half miles southwest of Irving College, 11 miles south of McMinnville, on the land of John Rogers, 400 yards northwest of Rogers' house. It is in St. Louis limestone, 700 feet below the Lee sandstone.

The mouth is in a small sink in thin woods, 100 yards above the corner of a field and 200 yards from the foot of the mountain. The cave is a quarter of a mile long and averages 20 feet in width and 6 feet in height. For the last 150 yards the roof becomes gradually so low that it almost joins the floor. The earth averages 4 feet in depth and a considerable quantity has been removed for niter. An old tramway has been built in the cave for 150 yards and it is now used to store apples and potatoes. Toward the back of the cave there are some short but interesting natural columns and stalagmites. The cave winds about a great deal, extending first north then west and then turning abruptly south and southwest.

No. 107. Henshaw Cave.

Location.—Five and a half miles southeast of McMinnville near the base of Cardville Knob on the land of Chas. Grove, a half mile northeast of Grove's house and the same distance southwest of Higginbotham Cave. This cave is a half mile from a good public road and about 5 miles from the Nashville, Chattanooga and St. Louis Railway. It is in St. Louis limestone, 700 feet below the Lee sandstone.

The mouth is small and is in the thick woods near the base of Cardville Knob. It extends downward at a steep angle for 15 feet. The cave is 400 yards long, 115 feet high and 25 feet wide. The earth on the floor is 4 feet deep. There are four good-sized hoppers near the mouth. On the east side of the cave and toward the back there are some very beautiful calcite deposits consisting of stalactites, stalagmites, terraces and rock-rimmed pools. At one place a small stream falls from a crevice in the roof into a deep hole in the floor.

Nos. 108 and 109. Higginbotham Cave.

Location.—Six miles southeast of McMinnville near the base of Cardville Knob on the land of Chas. Grove, a mile east of Grove's house on the north side of Blue Spring Cove. This cave is 6 miles from the Nashville, Chattanooga and St. Louis Railway, and a mile from the public road and is easily accessible. It is in St. Louis limestone, 700 feet below the Lee sandstone.

The mouth is 10 feet long and 5 feet wide and is situated in thin woods near the edge of an open pasture. The cave is very sinuous, but the general direction of the main passage is northwest. There is a small hole in the roof a short distance inside the mouth and very near it are a number of large natural columns and stalagmites known as the "Graveyard". The length of the main passage of this cave is 3 miles, while the numerous branches aggregate at least 5 miles or more. At the end of the main passage there is a large earth-floored room, 3 or 4 acres in area. There are two long ladders that it is necessary to climb up and two to descend, as well as many high places to climb over, one small hole through which it is necessary to wriggle, and a long, narrow passage through which one must crawl before reaching the Big Room. The way to the Big Room is marked by arrows, and there is a well trodden path for the whole distance. There are several places where the cave is damp and there are a good number of stalactites and stalagmites formed by the dripping water. Most of the cave, however,

is practically dry and in some places even dusty. Where it is dry there are none of these formations. In places the walls are coated with gypsum crystals, though these are not so abundant as they are in No. 104. The earth also contains many tiny, sparkling crystals. The width and height of this cave vary greatly but average respectively about 10 feet and 15 feet. There is no stream anywhere in the cave. The depth of the earth varies greatly, also, but apparently averages 5 or 6 feet. Some of it has been removed for fertilizing purposes.

WHITE COUNTY.

No. 45. Ward Cave.

Location.—A mile north of Sparta on the bank of the Calf Killer River on the land of W. J. Ward. This cave has a dairy house in its mouth. The mouth is 50 feet wide and 7 feet high. The cave is a quarter of a mile long. It is very wet inside and a large stream of water runs through it. There is but little earth and all has been flooded. There are no cave formations.

No. 46. Cline Cave.

Location.—One and a half miles northeast of Sparta on the land of of W. M. Cline, in pasture land 100 yards south of Cline's house. It is in St. Louis limestone and about 300 feet below the Lee sandstone.

The mouth is small and low and extends downward for a short distance. The cave is damp inside but there is no stream. This is a small cave as it is only 60 yards long and averages 5 feet in height and 7 feet in width. The earth on the floor is about a foot deep. There are few cave formations.

No. 47. Harris Cave.

Location.—One and a half miles northeast of Sparta on the land of Hal Harris at the top of a hill a quarter of a mile south of W. M. Cline's house. It is in St. Louis limestone.

The mouth is almost at the top of the hill in open woods, very small and triangular in shape and opens downward vertically for 15 feet. The cave extends in a northwesterly direction for about 150 yards, and consists of two or three good-sized rooms with narrow places between them. The roof is high, averaging at least 20 feet. The average width is 12 or 15 feet, but the main room is 40 feet wide. The loose earth is about 2 feet in depth and is damp but not wet. The stalactites and

stalagmites are few in number but the walls are beautifully scalloped and carved by water.

No. 48. Webster Cave.

Location.—Two miles northeast of Sparta, on the land of John Webster, 200 yards east of Sam Reese's house. It is in St. Louis limestone. The mouth proper is small and rectangular and is located in the southeast corner of a rather imposing rock shelter which is 50 feet wide and 6 to 10 feet high. The cave extends downward for a considerable distance after which it is very rough and irregular and for 50 yards narrow and sinuous. At the end of this narrow place it opens out into an almost circular room 100 feet in diameter. From here three or four small winding passages branch out. The length of this cave is about 300 yards and it averages 10 feet in height and 12 feet in width. It is damp near the mouth but in the main chamber the earth is almost dusty. Most of the loose earth seems to be in this chamber, where it is 6 feet deep or more. Stalactites are rare and there are no stalagmites, but the walls are fantastically carved by water. It is 200 yards from a road and 2 miles from the Sparta branch of the Nashville, Chattanooga and St. Louis Railway.

No. 49. Saltpeter Cave.

Location.—Three miles north of Ravenscroft in England's Cove on the land of J. S. Officer on the top of Cave Hill near the Sparta-Monterey road. It is in Mississippian limestone, 50 feet below the Lee sandstone.

There are two mouths, both of which have been enlarged by man. One is a round hole about 5 feet in diameter that extends vertically downward for 75 or 100 feet. Drill holes are plainly visible around the edges of the mouth and there are mounds of earth and broken rock about it. The other mouth is at the bottom of a sink-hole near the top of Cave Hill about 150 feet east of the first mouth. It slopes downward to the west for 30 feet and then opens downward vertically for at least 60 feet in a wide and deep chasm. There are drill holes at the back of this chasm and large mounds of earth near the mouth. It is said that much saltpeter was taken from this cave during the Civil War and was used in making gunpowder for the Confederacy. This cave was not explored because there was no way to get to the bottom. A sample was collected from inside the second mouth.

No. 50. Officer Cave.

Location.—Three miles north of Ravenscroft in England's Cove on the farm of J. S. Officer, on the hill north of Officer's barn and about 500 yards from his house. There is a public road about 500 yards from the cave and the railroad at Ravenscroft is only about 3 miles distant. It is in St. Louis limestone, 400 feet below the Lee sandstone.

The mouth is an oblong hole in the hillside and opens down into a good-sized chamber from which several forks extend in various directions. It is practically a dry cave. The main chamber is 75 feet in diameter and the roof is 20 feet high. There are three forks which extend for 50 yards or more, but become narrower toward the back. The loose earth is probably 5 or 6 feet deep and is coated by a thin white crust, possibly of niter. The main room of this cave is very beautiful, for stalagmites, stalactites, and natural columns of many curious and fantastic shapes and groupings are abundant on all sides. Some of the stalagmites are especially large and beautiful, many being as white as alabaster. There is one stalagmite or column just inside the mouth 17 feet high and 6 feet in diameter. A good deal of light enters the cave through the mouth and it has the characteristic green hue that the light entering through the mouth of a cave seems to possess, at least when leaves are on the surrounding trees.

No. 82. Journigan Cave.

Location.—A fourth of a mile northeast of Quebeck, on the land of F. Journigan, at the bottom of a sink-hole 30 feet deep and 50 feet in diameter, in an old field. This is a small, wet cave that extends about 50 yards and averages 4 feet in width and 5 feet in height. No stalactites or stalagmites are present, but the roof and walls are covered by a layer of yellow mud left by waters that have dissolved the limestone in which it occurred as an impurity. Practically the only earth in the cave has been washed in.

Discussion of the Chemical Analyses of the Cave Deposits of Tennessee

BY L. C. GLENN.

The examination of the caves of Tennessee, the results of which have been given in the preceding article by Mr. Thomas L. Bailey, was undertaken primarily to determine their value as a possible source of niter supply in case such should be needed in prosecuting the present war. It is well known that during the war of 1812 and again during the Civil War, the caves of Tennessee, Kentucky and other states were used to supply niter for making munitions, and they were in that way an important element in the prosecution of those wars. While the conditions of warfare and the type of explosives have greatly changed, nitrates are still essential in munition manufacture. It was anticipated that the quantity of material might not be great enough to make such source important under present conditions of warfare, but it was deemed of sufficient importance to warrant the investigation.

The analyses given below show that in none of the many caves examined is the percentage of nitrate high enough to make it possible to work the cave earth in competition with the Chilean nitrate deposits or with the nitrates fixed from the atmosphere. Nitrate occurs in the cave earth chiefly as calcium nitrate. In the manufacture of saltpeter in former days, this calcium nitrate was leached out of the cave earth with water and the resulting solution was allowed to percolate through wood ashes. During this percolation an interchange was made between the calcium of the nitrate and the potash of the ashes, transforming the solution into potassium nitrate. The process of manufacturing was crude and primitive and involved the burning of large quantities of wood to furnish ashes containing the potash necessary for the above chemical change.

The study of our Tennessee caves has not, however, been fruitless, since caves are objects of much popular and scientific interest aside from their use as a possible source of nitrate deposits. It is quite desirable that the people of the State may have such information concerning their many caves as Mr. Bailey has given in the preceding article. The number of caves will be a surprise to many. Those inter-

ested in caves may, with the guidance of the preceding article, more readily find and visit them than has heretofore been possible. The archaeologist, especially, will have his attention called to many of them as repositories of Indian remains and other relics and while many of them have been ransacked for such remains there are doubtless many rich finds still in store for those who dig in certain of the known caves, and probably other caves yet undiscovered like No. 29, Bone Cave, in Pickett County, containing Indian remains of great interest.

The chemical analysis of the cave deposits was begun by Dr. Paul C. Bowers, who analyzed twenty-three samples. The work was continued by Dr. J. I. D. Hinds, who analyzed sixty-five, making a total of eighty-eight in all. The only elements the chemists were asked to determine were potassium and nitrogen. The potassium has been computed in the following table as potassium oxide, K_2O and the nitrogen as nitrate iron, NO_3. Doctor Hinds reports that many of the samples contain sulphate, probably mostly calcium sulphate in the form of gypsum, and that many contain a very small amount of sodium chloride. One showed the presence of calcium fluorite while many also contain soluble carbonates. One sample was without number and is not included in the following table. It contained 0.03 per cent of K_2O and 0.12 per cent of NO_3.

ANALYSIS OF CAVE DEPOSITS OF TENNESSEE.

Sample No.	Laboratory No.	Per cent K_2O	Per cent NO_3	Analyst
1	293	trace	trace	Hinds
2	284	0.70	0.00	Bowers
3	281	0.04	trace	Bowers
4	289	0.11	trace	Hinds
5	280	0.04	0.02	Bowers
6	306	0.17	1.90	Hinds
7	274	0.05	0.00	Bowers
8	303	0.15	trace	Hinds
9	297	0.23	1.50	Hinds
10	272	0.01	0.00	Bowers
11	275	0.05	0.00	Bowers
12	307	0.20	0.45	Hinds
13	348	0.00	0.00	Hinds
15	347	0.35	0.48	Hinds
16	349	0.12	0.00	Hinds
17	351	0.03	0.03	Hinds
18	350	0.10	0.01	Hinds

Sample No.	Laboratory No.	Per cent K_2O	Per cent NO_3	Analyst
19	352	1.02	1.45	Hinds
22	322	0.05	0.00	Hinds
24	316	0.03	0.00	Hinds
26	287	0.00	0.00	Bowers
27	325	0.25	0.10	Hinds
28	326	0.13	0.15	Hinds
29	319	0.05	0.00	Hinds
30	320	0.15	0.26	Hinds
31	318	0.04	0.25	Hinds
32	311	0.11	0.00	Hinds
33	317	0.04	trace	Hinds
34	299	0.17	0.15	Hinds
35	321	0.04	0.00	Hinds
36	301	0.77	0.37	Hinds
37	302	0.70	0.18	Hinds
38	282	0.19	trace	Bowers
39	310	0.09	0.00	Hinds
42	288	trace	trace	Hinds
43	291	0.12	trace	Hinds
44	283	0.05	0.00	Bowers
46	269	0.10	0.00	Bowers
47	268	0.10	0.05	Bowers
48	271	0.04	0.02	Bowers
49	329	0.07	0.00	Hinds
50	327	0.07	trace	Hinds
51	324	0.32	0.42	Hinds
52	328	0.17	0.53	Hinds
53	323	0.05	0.30	Hinds
54	296	0.20	1.15	Hinds
56	312	0.14....	trace	Hinds
57	309	0.00	0.10	Hinds
58	294	0.68	0.93	Hinds
59	300	0.97	0.10	Hinds
60	315	0.38	trace	Hinds
62	265	0.16	0.02	Bowers
69	266	0.14	0.01	Bowers
71	332	0.25	0.11	Hinds
72	330	0.02	0.30	Hinds
73	340	0.04	0.75	Hinds
74	335	0.10	0.23	Hinds
75	334	0.07	0.45	Hinds
76	333	0.43	1.75	Hinds
77	345	0.22	0.50	Hinds
78	286	0.31	trace	Bowers
79	270	0.07	0.01	Bowers

Sample No.	Laboratory No.	Per cent K_2O	Per cent NO_3	Analyst
80	285	trace	trace	Bowers
83	277	0.03	0.01	Bowers
84	278	0.03	trace	Bowers
85	292	0.14	0.11	Hinds
86	276	0.28	0.16	Bowers
87	279	0.07	0.63	Bowers
88	344	0.03	0.10	Hinds
89	342	0.05	0.20	Hinds
90	339	0.00	trace	Hinds
91	337	0.03	trace	Hinds
92	336	0.44	1.12	Hinds
93	314	0.68	0.37	Hinds
95	305	0.06	0.00	Hinds
96	308	0.08	0.15	Hinds
98	295	0.18	trace	Hinds
99	298	0.01	0.00	Hinds
100	313	0.54	trace	Hinds
101a	290	0.37	2.39	Hinds
101b	304	0.87	0.75	Hinds
102	264	0.17	0.00	Bowers
103	267	0.04	0.01	Bowers
104	343	0.27	0.30	Hinds
106	338	0.05	0.30	Hinds
107	341	0.13	0.07	Hinds
108	331	0.32	0.09	Hinds

Publications of Geological Survey of Tennessee Issued.

The following publications have been issued by the present Survey, and will be sent on request *when accompanied by the necessary postage.*

BULLETIN No. 1—Geological Work in Tennessee.

A. The establishment, purpose, object and methods of the State Geological Survey; by Geo. H. Ashley, 33 pages, issued July, 1910, postage, 2 cents.

B. Bibliography of Tennessee Geology and Related Subjects; by Elizabeth Cockrill, 119 pages; postage, 3 cents.

BULLETIN No. 2—Preliminary Papers on the Mineral Resources of Tennessee, by Geo. H. Ashley and others.

A. Outline Introduction to the Mineral Resources of Tennessee, by Geo. H. Ashley, issued September 10, 1910; 65 pages; postage, 2 cents.

D. The Marbles of East Tennessee, by C. H. Gordon; issued May, 1911; 33 pages; postage, 2 cents.

E. Oil Development in Tennessee, by M. J. Munn; issued January, 1911; 46 pages; postage, 2 cents.

G. The Zinc Deposits of Tennessee, by S. W. Osgood; issued October, 1910; 16 pages; postage, 1 cent.

BULLETIN No. 3—Drainage Reclamation in Tennessee; 74 pages; issued July, 1910; postage, 3 cents.

A. Drainage Problems in Tennessee, by Geo. H. Ashley; pages 1-15; postage, 1 cent.

B. Drainage of Rivers in Gibson County, Tennessee, by A. E. Morgan and S. H. McCrory; pages 17-43; postage, 1 cent.

C. The Drainage Law of Tennessee; pages 45-74; postage, 1 cent.

BULLETIN No. 4—Administrative Report of the State Geologist, 1910; issued March, 1911; postage, 2 cents.

BULLETIN No. 5—Clays of West Tennessee, by Wilbur A. Nelson; issued April, 1911; postage, 4 cents.

BULLETIN No. 9—Economic Geology of the Dayton-Pikeville Region, by W. C. Phalen; issued May, 1911; postage, 4 cents.

BULLETIN No. 10—Studies of the Forests of Tennessee.

A. An Investigation of the Forest Conditions in Tennessee, by R. Clifford Hall; issued April, 1911; 56 pages; postage 3 cents.

B. Chestnut in Tennessee, by W. W. Ashe, issued December, 1911; postage, 2 cents.

C. Yellow Poplar in Tennessee, by W. W. Ashe, issued January, 1914; 55 pages; postage, 3 cents.

BULLETIN No. 13—A Brief Summary of the Resources of Tennessee, by Geo. H. Ashley; issued May, 1911; 40 pages; postage, 2 cents.

BULLETIN No. 14—The Zinc Deposits of Notheastern Tennessee, by A. H. Purdue; issued September, 1912; 69 pages; 30 illustrations; postage, 3 cents a number.

BULLETIN No. 15—Administrative Report of State Geologist, 1912.

BULLETIN No. 16—The Red Iron Ores of East Tennessee, E. F. Burchard; issued November, 1913; 172 pages; postage, 8 cents.

BULLETIN No. 17—The Water Powers of Tennessee, by J. A. Switzer; issued April, 1914; 137 pages; postage, 8 cents.

BULLETIN No. 18—Administrative Report of the State Geologist, 1914.

BULLETIN No. 19—Elevation in Tennessee, by Elizabeth Cockrill; issued 1917, 80 pages; postage, 3 cents.

MAPS—Map of Lewis County, 1915; postage, 2 cents.
Geological Map of Tennessee, 1915; postage, 15 cents.
Map of Rutherford County, 1916; postage, 2 cents.
Map of McNairy County, 1916; postage, 2 cents.

"THE RESOURCES OF TENNESSEE"—This is a quarterly magazine, devoted to the description, conservation and development of the State's resources. Postage, 2 cents a number. The following are the volumes and numbers issued, with the title of the principal papers in each number:

Vol. I. No. 1—The utilization of the small water powers in Tennessee, by J. A. Switzer and Geo. H. Ashley. (Out of print).

No. 2—The Camden chert—an ideal road material, by Geo. H. Ashley.
The Fernvale iron ore deposit of Davidson County, by Wilbud A. Nelson.
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No. 4—Coal resources of Dayton-Pikeville area, by W. C. Phalen.

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Tennessee to Have Another Great Water Power, by George Byrne.
Manufacture of Sulphuric Acid in Tennessee in 1911, by Wilbur A. Nelson.

No. 2—The Ocoee River Power Development, by J. A. Switzer.
Exploration for Natural Gas and Oil at Memphis, Tenn., by M. J. Munn.

No. 3—The Power Development at Hale's Bar, by J. A. Switzer.
Notes on Lead in Tennessee, by Wilbur A. Nelson.

No. 4—The Tennessee Academy of Science.
The Preliminary Consideration of Water Power Projects, by J. A. Switzer.
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No. 5—The Growth of Our Knowledge of Tennessee Geology, by L. C. Glenn.

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No. 10—The Iron Industry of Lawrence and Wayne counties, by A. H. Purdue.
Some Building Sands of Tennessee, by Wilbur A. Nelson.

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The Iron Ore Deposits in the Tuckahoe District, by C. H. Gordon and R. P. Jarvis.

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Vol. VIII. No. 1—Dr. A. H. Purdue, by L. C. Glenn.
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Manganese Deposits of Bradley County, by A. H. Purdue.
Barite Deposits of the Sweetwater District, East Tennessee, by C. H. Gordon.

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THE RESOURCES OF TENNESSEE

A MAGAZINE DEVOTED TO THE DESCRIPTION, CONSERVATION AND DEVELOPMENT OF THE RESOURCES OF TENNESSEE

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STATE OF TENNESSEE
STATE GEOLOGICAL SURVEY
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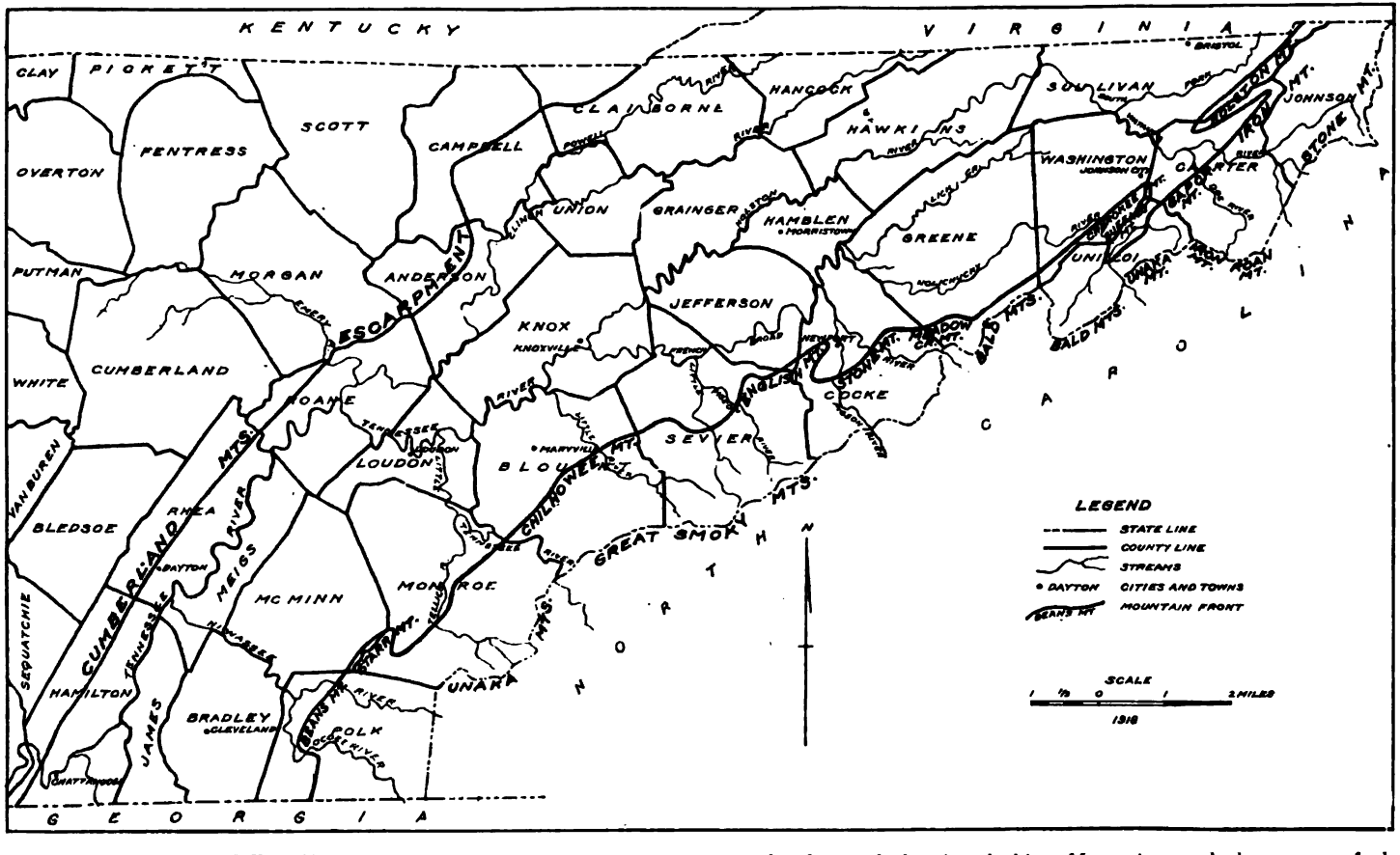

FIGURE 1. Map of East Tennessee showing the main drainage system, the front of the Appalachian Mountains, and the names of the principal mountain ranges.

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Manganese Deposits of East Tennessee

By G. W. Stose and F. C. Shrader.[1]

Scope of Report

This report presents briefly the results of field work in East Tennessee by geologists of the U. S. Geological Survey in cooperation with and assisted by the State Geological Survey of Tennessee. All the operating mines and most of the prospects and known occurrences of manganese ore in this part of the State were visited, and the ore deposits were studied with a view to determining their relation to the underlying rocks and to the surface features. In the hope of stimulating the mining of manganese ore, and thus increasing the output of this mineral, so much needed in the steel industry during the prosecution of the present war, these geologists gave such professional assistance and advice as they could in the field to the operators of the mines and to the owners of property carrying manganese ore deposits. In this report are given not only a tabular statement of all the known deposits and descriptions of some of the typical mines, but suggestions are made as to where conditions may be favorable for further prospecting of the ore. In a later report in this quarterly the same writers expect to describe all the mines and prospects more fully and possibly give some definite recommendations for the prospecting of undeveloped tracts where detailed work will warrant it.

Acknowledgments.

In the examination of the manganese properties of the State the writers have been courteously received by the owners and operators, who gave every available assistance to the study of their mines and

[1]The field work in this area was done under a co-operative agreement between the State Geological Survey and the U. S. Geological Survey, the latter bureau being represented by Messrs. G. W. Stose and F. C. Schrader. This report is published by permission of the Director of the U. S. Geological Survey. The remainder of this report, consisting of a description of all mines and prospects, the manuscript of which is not yet completed, will appear in the October issue of the Resources of Tennessee. Mr. Arthur McFarlan, representing the State Geological Survey, assisted in this latter work.

properties. In many instances conveyance was furnished, accompanied by a man familiar with the property, which greatly facilitated the work. Special mention should be made of the Southern Manganese Corporation of Birmingham, whose President, Mr. Theodore Swann, arranged to have their representative at each mine and prospect, from Mountain City to Sweetwater. Assistance was rendered in return by the writers, who gave their opinion as to the ore and its relations and advice as to mining and further prospecting.

Previous Work.

The occurrence of manganese ore in East Tennessee has been known for many years. Troost[1] refers to its occurrence in Cocke County as early as 1839. Safford[1*] in 1869 refers to its occurrence in several localities. Killibrew and Safford[2] in 1874 refer to deposits in Greene County. Bailey Willis,[3] in the Census report for 1880, gives analyses of samples of ore from Sevier and Carter counties. Penrose, in his report on manganese,[4] describes the deposits known in the State of Tennessee in 1890. Harder in his report of 1910[5] brings the information up to that date. Buchard in a report on the iron ores[6] refers to the occurrence of manganese with the iron ores of Monroe County. Nelson, in the first volume of the Resources of Tennessee,[7] calls attention to a new deposit in Tennessee. Purdue in the same publication for 1916,[8] reviews the known deposits of the State, and in the volume for 1918 describes another deposit in Bradley County. The present

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[1]Troost, Gerard, Fifth Geologic Report on the State of Tennessee, pp. 22 and 23, 1840.

[1*]Safford, James M., Geology of Tennessee, pp. 224 and 505, 1869.

[2]Resources of Tenn.: State Board of Agric., pp. 268 and 400, 1874.

[3]U. S. Census Report, Mining Industries, Vol. 15, pp. 336 and 345, 1880.

[4]Penrose, R. A. F., Manganese, Its Uses, Ores, and Deposits: Ark. Geol. Surv. Ann. Rept. for 1890, Vol. 1, pp. 414-416, 1891.

[5]Harder, E. C., Manganese deposits of the United States: U. S. Geol. Surv. Bull. 427, pp. 72 to 76, 1910.

[6]Burchard, E. F., The Red iron ores of East Tennessee: Geol. Surv. of Tennessee Bull. 16, pp. 52-54, 1913.

[7]Nelson, Wilbur A., A new manganese deposit in Tennessee: The Resources of Tenn., Vol. 1, No. 6, pp. 220-228, 1911.

[8]Purdue, A. H., Notes on manganese in East Tennessee: Resources of Tennessee, Vol. VI, No. 2, pp. 111-123, 1916, and Vol. VIII, No. 1, pp. 46-47, 1918.

authors have made use of these earlier reports as well as those relating to similar deposits in Virginia.

GEOGRAPHY OF THE REGION.

SURFACE FORMS.

East Tennessee is partly mountainous, partly lowland. The Tennessee-North Carolina boundary for the most part follows the crest of one or another of the highest ranges of the Appalachian Mountains and has a general west-southwest direction. This crest is in part the watershed between Atlantic and Gulf drainage, but many of the larger tributaries of Tennessee River head in North Carolina and flow westward through deep gorges in the mountains. The Appalachian Mountains in this region comprise several high parallel ranges which are not of the same length but overlap one another and inclose deep reentrant valleys. These intermontane valleys open out into the Great Valley or Valley of East Tennessee, along the northwest foot of the Appalachian Mountains. In this valley are a few high knobs and single linear ridges which trend in the same general west-southwest direction. The east-facing Cumberland escarpment or edge of the Cumberland Plateau forms the western boundary of the Valley of East Tennessee.

Holston Mountain is the westernmost ridge of the Appalachian Mountains at the Virginia State line. It extends into Tennessee as a prominent mountain ridge over 4,000 feet high for 25 miles, terminating rather abruptly near Elizabethton. The narrow arm of the Great Valley which lies back of it is drained chiefly southwestward by Stony Run, but the upper part drains into Virginia. This shut-in valley draining northeastward is called Shady Valley. East of Stony Run and Shady Valley is another prominent ridge called Iron Mountain which also trends southwest and extends into Tennessee about 40 miles. Its southwestern part, however, is dwarfed and it generally dies down to such small hills that the names Gap Creek Mountain and finally Little Mountain are applied to it.

The main mass of the Appalachian Mountains lies still farther east and has various local names. Its main crest near the Virginia State line is called Stone Mountain. This is followed by the east boundary of Tennessee to the gorge of Watauga River. South of Doe River the crest is known as Roan Mountain, and is over 6,000 feet in altitude.

The State boundary turns westward here, following the crest of the range which is locally called Iron Mountain and further on Unaka Mountain and finally Bald Mountains. All of these mountains rise to about 4,500 feet in altitude. The main Bald Mountains bend sharply southwestward and form the mountain front in Greene County, where for a short distance the State line is not more than 3 miles from the Great Valley. The low irregular mountains which extend northeastward from this sharp bend in Bald Mountains merge into two distinct outlying ridges south of Johnson City called Cherokee and Buffalo Mountains, which correspond in position to Holston Mountain northeast of Johnson City. A reentrant arm of the Great Valley, similar to that of Stony Run, extends southwestward between Buffalo Mountain and Unaka Mountain and terminates above Erwin near Nolichucky River where the mountains close in.

Southwest of French Broad River the State boundary line follows the crest of the Great Smoky Mountains, a massive range which rises to an altitude of over 6,000 feet. Southwest of Little Tennessee River this great mountain range is known as the Unaka Mountains, but on the earliest maps of the region Unaka and Great Smoky were both applied to the whole of these higher ranges of the Appalachian Mountains. Where the high mountains break down at Hiwassee River the State line turns south directly to the Georgia State line. The mountainous tract northwest of the Great Smoky and the Unaka Mountains consists mostly of irregular ridges having local names, but English Mountain, southwest of Newport, and Stone, Neddy, and Meadow Creek mountains northeast of Newport form a more or less continuous frontal or outlying ridge corresponding in a general way to Holston Mountain. Chilhowee Mountain, which extends from Little Pigeon River to the Little Tennessee south of Knoxville, is a similar though less prominent outlying ridge, and Starr and Beans mountains are other outlying ridges near the southern boundary of the State.

DRAINAGE.

East Tennessee is drained practically throughout by Tennessee River. (See figure 1.) A very small part of the extreme southeast corner drains southward through the Conasauga River into the Gulf of Mexico. The small part of the northeast corner which drains northward into Virginia is in the Holston drainage system, a branch of the

Tennessee. Although the name Tennessee River is applied only to the river below Knoxville where the Holston and French Broad unite, the Holston above that point is the direct continuation of the main stream which flows in a general southwest course. Holston River heads in Virginia and its two main branches unite at Kingsport. Its North Fork lies almost wholly in Virginia. Its South Fork, which enters the State east of Bristol, is joined from the east by Watauga River 25 miles from the State line. The latter river and one of its main tributaries, Elk Creek, head in the mountains in North Carolina. With Doe River, another main tributary, they drain most of Carter and Johnson counties.

The French Broad River heads in the mountains of North Carolina and flows westerly. It is first joined from the south by Pigeon River, and then from the north by Nolichucky River, both of which head in North Carolina. The latter has a long tributary from the northeast, Lick Creek, which lies entirely within the valley and is a direct continuation of the main southwestward-flowing part of the Nolichucky and French Broad. Farther down stream, the French Broad is joined from the south by Little Pigeon River, which heads within the State and drains much of Sevier County.

A short distance below Knoxville, Tennessee River is joined from the south by Little River, which heads in the Great Smoky Mountains. Farther down stream, it is augmented by the Little Tennessee, a large stream which heads far back in the mountains of North Carolina and in the high mountains flows in a deep gorge which separates the Great Smoky and Unaka mountains. Its main branch, Tellico River, drains a large part of eastern Monroe County and joins the Little Tennessee near Morganton.

Hiwassee River is the main branch of the Tennessee in the southern part of the State. It heads in North Carolina and its main tributary, Ocoee River, heads in Georgia, and together they drain most of Polk County in the southeast corner of the State. A small part of the county is drained south to the Gulf by Conasauga River, as previously described. Just above Chattanooga the Tennessee is joined from the south by Chickamauga Creek, which heads in Georgia and drains but a small part of Tennessee.

All the above described tributaries of the Tennessee enter it from the east and therefore receive the run off from the Appalachian Moun-

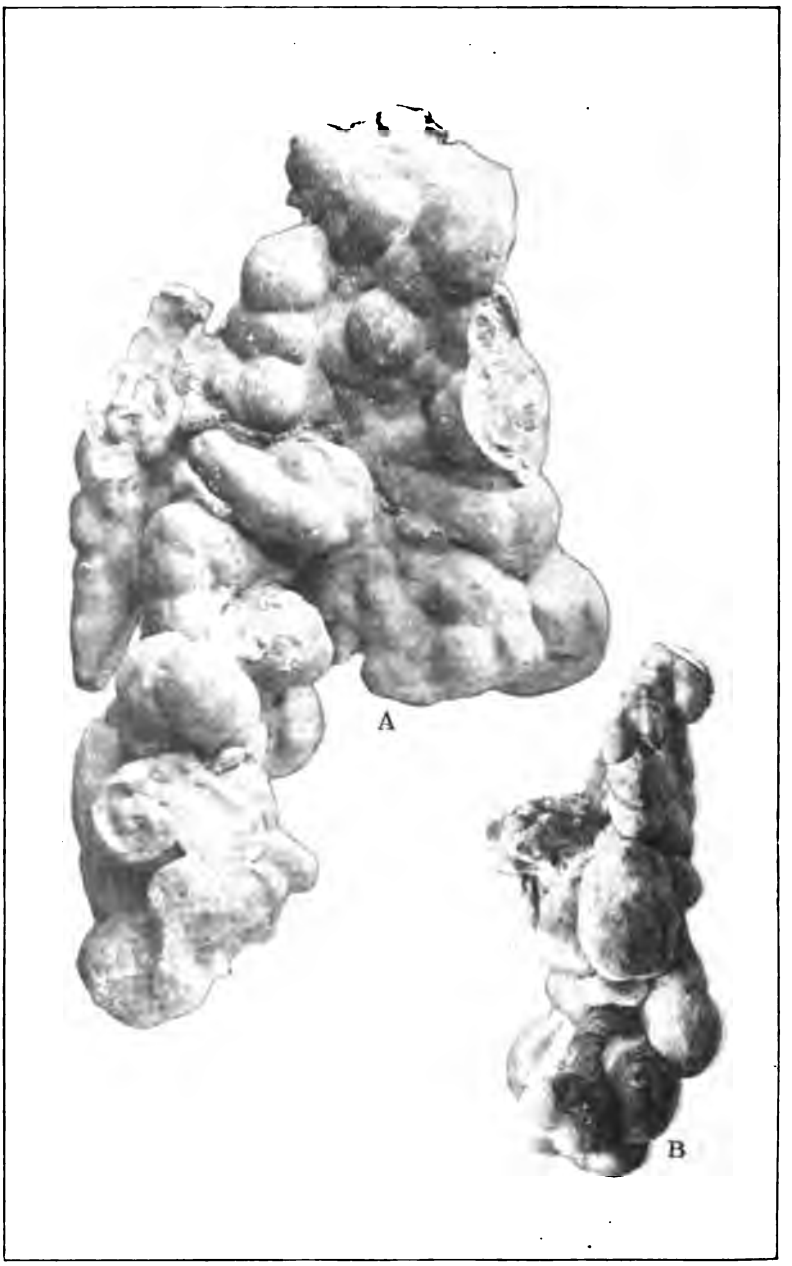

FIGURE 2. Nodular manganese ore, called grape ore, from Shouns' prospect near Mountain City, Johnson County.

tains. They are large streams and have steep gradients, so that they represent great potential water power. Some of this power is now being converted into electricity which is transmitted to distant parts of the State and is being utilized to light many of the larger cities and to furnish power to many industries. A new industrial South awaits the further development of the latent powers of these waters.

The only stream of any size which enters the Tennessee from the northwest is Clinch River. It heads in Virginia and flows southwestward. It is joined from the north by Powell and Emery rivers before it unites with the Tennessee near Kingston.

THE MANGANESE DEPOSITS.

Most of the known manganese deposits of East Tennessee consist of heavy, black, hard minerals which somewhat resemble iron ore in appearance and occurrence and are therefore frequently called black iron ore or steel ore by farmers. These minerals are oxides of manganese and occur most commonly in small masses in the soil and underlying clay, where they are discovered in plowing or in road cuts, or are found as float scattered over the fields. Within the clay they appear as scattered irregular masses ranging in size from minute particles to that of a bushel basket or larger, occurring as botryoidal masses, or rounded nodules, and are then called "nut" ore. The nodules may be united into clusters resembling bunches of grapes and then constitute "grape" ore. (See fig. 2.) Ore that is scattered through the clay must be washed to remove the clay and other impurities and is generally spoken of as wash ore. At and near the surface pebbles and fragments of rocks, usually quartzite and sandstone from the mountains, are mixed with the ore in the clay and must be washed away with the clay or must be removed by hand picking after washing. Some of the masses of manganese oxide ore are large enough to be mined as lump ore and are hand picked and shipped without washing. Other masses fill crevices and seams in sandstone and chert and the rock must be crushed and the ore separated by log washer or other machinery, or by hand picking. Only one deposit is known in the area in which the ore is not a manganese oxide. This ore, which is a carbonate of manganese, is light gray to white and the crystalline portion resembles coarse limestone in appearance but is heavier than limestone. It occurs as layers or lenses in solid bedrock.

Manganese Minerals.*

The manganese-bearing ores of the eastern United States fall into two general groups—manganese ores and manganiferous iron ores. Both of these occur in the Appalachian region of Tennessee. The manganese ores are of much greater value than the manganiferous iron ores and therefore in the past have been chiefly sought, but the greatly increased demand for manganese has caused a growing demand for manganiferous iron as well as manganese ores and these are now being mined in a number of localities in East Tennessee.

The manganese ores in this region are chiefly oxides, four of which are commonly present and will be here described. They belong to the group of brown to black oxides and hydrous oxides, several of which cannot be positively distinguished without analyses. In general a manganese mineral that is non-crystalline or amorphous and is hard is provisionally classed as psilomelane. One that is crystalline and fairly hard is classed as manganite, but if soft it is regarded as pyrolusite. If it is soft and shows no sign of crystalline structure nor of the compact firm amorphous structure of psilomelane, it is classed as wad. The following descriptions are in part summarized from Hewett[1] with modifications and additions.

Psilomelane.—Psilomelane (H_4MnO_5) generally with some K and Ba) is a bluish or grayish black dense amorphous mineral, usually having rounded or botryoidal surface form, concentric and somewhat radiate structure, and conchoidal fracture. A characteristic botryoidal form is illustrated in fig. 2. Psilomelane has a hardness of 5 to 6 (cannot be scratched with a knife), and a specific gravity of 3.7 to 4.7. Its composition is complex and apparently not definite. It always contains water, the quantity of which varies from 2.5 to 6 per cent, and it may contain as much as 17 per cent of barium and 5 per cent of potassium. These elements are believed by some to be mechanically admixed and not chemically combined. The percentage of manganese varies from 50 to 57. This is one of the commonest

*A simple way to distinguish manganese ores, from iron ores, in the field is by making a mark on a piece of white chert or quartz pebble with the ore to be determined. Manganese makes a black mark. Iron in the form of hematite makes a red mark, or in the form of limonite a yellowish brown mark. Iron containing some manganese generally makes a brownish black mark.—W. A. N.

[1]Hewett, D. F., Loc. cit., pp. 39 and 40.

manganese minerals in the Tennessee deposits and forms more than 75 per cent of the washed ore.

Manganese.—Manganese ($Mn_2O_3.H_2O$) is a heavy, black, generally crystalline mineral. It has a hardness of 4 (moderately hard), and a specific gravity of 4.2 to 4.4. It craystallizes in the orthorhombic form and the crystals are generally bladed, wedge-shaped, or needle like. The crystals are black, and brilliant and metallic in appearance. The needle-like crystals in "needle ore" are generally arranged radially and some form complete balls more than 2 inches in diameter. (See fig. 3.) In other needle ore the silky crystals are parallel, and are over 2½ inches long. The mineral contains theoretically 62.4 per cent of manganese and 10.3 per cent of water. It is frequently associated with psilomelane in the Appalachian deposits, in which case it generally lines cavities in the psilomelane ore. Its presence is generally regarded as an indication of high grade ore.

Pyrolusite.—Pyrolusite (MnO_2, generally with a little H_2O) is a grayish black to black mineral with crystalline or granular structure. It is decidedly soft, having a hardness of 2 to 2.5 (can be scratched by the finger nail), and a specific gravity of 4.8. Its color is steel gray, as distinct from the black of manganite. Some of the ore classed as pyrolusite, including certain soft powdery graphite-like ore, is of much lower specific gravity. Pyrolusite contains theoretically 63.2 per cent of manganese. It is believed to have been derived from manganite by the loss of water, and is known to have been so formed in specimens where the radiate crystal form of manganite is preserved although the mineral has become soft, light in weight, and steel gray or dull gray in color. Much of the mineral that has heretofore been identified as pyrolusite in the Appalachian deposits has the crystalline form and hardness of manganite. Chemically, however, it appears to be intermediate between the two minerals.

Wad.—Wad is a dark, very soft earthy mineral which is a mixture of manganese oxides, water, and other materials, such as clay, iron and barium. It is generally a loosely coherent brown or black powder, not sharply distinguished from the manganiferous clay with which it is usually associated. It contains from 30 to 42 per cent of manganese and 7 to 10 per cent of water, whereas the manganiferous clay carries only 5 to 10 per cent manganese.

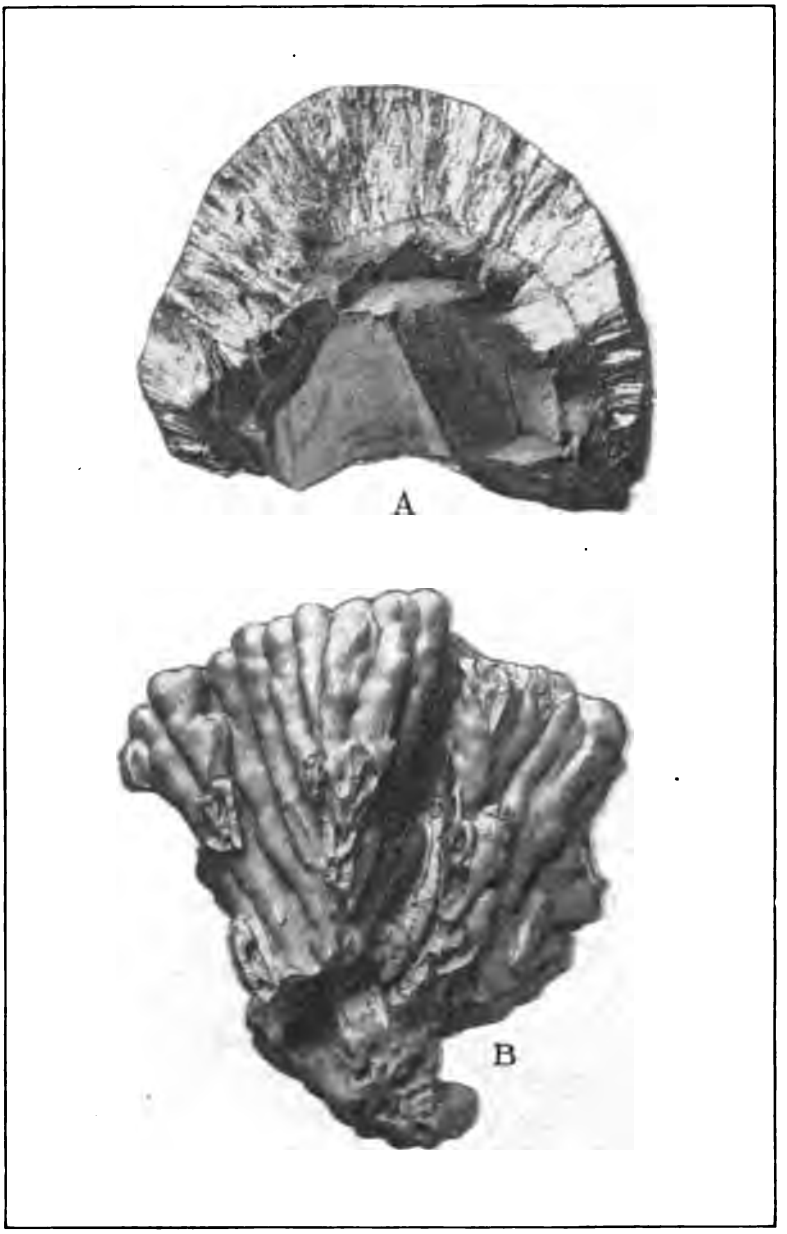

FIGURE 3. a, Needle ore. A shell of radiate needle crystals of manganite surrounding a nucleus of psilomelane. Embree mine, Bumpass Cave, Unicoi County.

b, Radiate cluster of "stalactitic" rods of psilomelane. Dry Run mine, Johnson County.

Manganiferous Iron Ores.—The manganiferous iron ores of the Appalachian region are simply mixtures of manganese oxides with iron ore in various proportions. The iron ore is generally brown ore ($Fe_2O_3+H_2O$) and contains a variable amount of water. The manganese is generally in the form of psilomelane, though manganite is common in some places. The iron and manganese oxides occur both as a mixture of the two minerals each readily distinguishable in the hand specimen and a mixture or compound in which the minerals are so intimately and minutely mixed that it is impossible to tell whether it is a mechanical mixture or a chemical combination. The amount of manganese in manganiferous iron ore varies from 1 to over 40 per cent. The higher grades are used in the manufacture of spiegleisen and ferromanganese, and the lower grades, down to 3 per cent, are used in the manufacture of high-manganese pig iron.

Rhodochrosite.—Rhodochrosite ($MnCO_3$) is a pink mineral, generally crystalline with a cleavage like calcite, but differing from that mineral in color and higher specific gravity. It has a hardness of 4, specific gravity of 3.6, and contains theoretically 48 per cent of manganese.

The crystalline mineral that resembles rhodochrosite, which is present in East Tennessee in only one deposit so far as known, is white and occurs in a mass made up of small rhombic crystals. An analysis of the crystalline rock shows the presence of considerable calcium and magnesium and the mineral is probably a calcium-magnesium-manganese carbonate not heretofore described. The analysis shows it to contain only 9 per cent of manganese. With the crystalline mineral is an amorphous or minutely crystalline substance, white to buff banded, containing thin laminae of a black metallic mineral, probably psilomelane. This banded material is apparently of later origin than the crystalline mass, and is also a manganese mineral, probably a carbonate like the crystals. An analysis of the banded white portion shows it to contain 26 per cent manganese and considerable calcium.[1]

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[1]It should be stated in connection with the above description of manganese minerals that on account of impurities in the minerals themselves, and of the presence of foreign material such as rock fragments, clay, and sand associated with the ores a deposit never yields the full percentage of manganese that the predominant minerals theoretically contain.

Mineral association.—In many of the deposits of the Appalachian region psilomelane nodules are inclosed in wad and may have been formed from it by the reduction of its contained water. Many nodules of psilomelane, however, are shown on polished section to be composed of alternate thin layers of hard psilomelane and softer ore, probably manganite. Manganite also lines cavities and fills sharply defined veinlets in psilomelane, and it is here clearly later in origin. As manganite is more hydrous than psilomelane, there is shown to be no uniform order of deposition from the more hydrous to the less hydrous or *vice versa*. However, the observed alteration of manganite to pyrolusite and the supposed change of wad to psilomelane indicate progressive dehydration after their formation.

The clay in which the manganese ores occur is generally highly colored yellow to deep red by iron oxide, but some is gray to black with manganese where it merges into wad. Limonite and manganiferous iron ore are often intimately mixed with the purer manganese ores, but are more plentiful in the superficial layers associated with the sand and gravel wash. The iron ores are therefore apt to be siliceous and some are highly siliceous. Sericite is a common constituent of the metamorphosed shales associated with the bedrock and is present in some of the clay associated with the ore, but most of the clay close to the ore is free from it.

There are grains of quartz in the ore-bearing clay, especially in the superficial layers, which are residual from the decomposition of quartzose rocks, but quartz also occurs in other forms which are evidently secondary and was deposited after the decomposition of the rock. A microcrystalline variety occurs as thin veinlets in the clay and in places it forms rounded nodules up to 2 inches in diameter. Quartz also occurs in some deposits as minute doubly terminated needle-shaped crystals containing rounded nuclei of calcite. Bauxite and wavellite are associated with the manganese in a few places.

Rocks With Which the Ore is Associated.

The manganese deposits are associated with different groups of rocks in the different parts of the State, and the determination of the relation of the deposits to these groups of rocks is of much importance in the study of the deposits for the purpose of giving aid to mining or advice for further prospecting.

There are 8 modes of occurrence of the manganese ores in this region, based chiefly on the rocks with which they are associated, and therefore the rocks that occur in East Tennessee will first be briefly described.

The rocks of the region are chiefly limestone, sandstone, and shale which occur in layers one above the other in apparently no particular order or arrangement and are tilted at various angles from horizontal to vertical. They are called sedimentary rocks because they were originally sediments, such as sand, mud, and calcareous silt, deposited from water. On close study the various layers are found to have certain characters by which they may be identified, and each layer occuplies a particular position with respect to the others. They have thus been classified and arranged one above the other in the order in which they are found in the rock exposures, and those which are at the bottom are the oldest, as they were deposited first.

The oldest rocks present in East Tennessee are crystalline rocks on which the sediments rest. These crystalline rocks include granite and allied rocks and schists, some of which were once lavas. They occur only in the Appalachian Mountains on the eastern border of the State. Although some manganese deposits occur in similar rocks in Virginia, none are known to so occur in Tennessee.

Overlying the crystalline rocks is a thick series of hard sandstones (called quartzite, grits, and conglomerates) and finer grained hard rocks such as slates and shales. A few thin layers of impure limestone and limy shale occur with some of the slates. These rocks are more resistant to erosion and solution than are the younger limestones and shales and therefore they form much of the Appalachian Mountains in the extreme eastern part of the State. There are many rock layers or formations which have been distinguished and named in this series but it is not necessary to give their names here. However, the uppermost formation of the series, a white sandstone or quartzite called the Erwin quartzite in places and the Hesse quartzite in others, is here referred to because one of the classes of manganese deposits occurs in the residual clays close to its top.

Overlying these sandstones and slates is a great thickness of limestones in which are a few shales and softer sandstones. These beds are in general rather soluble and are worn away faster than the harder sandy rocks previously described and therefore occupy low

lands which lie northwest of the Appalachian Mountains and form part of the Valley of East Tennessee. The limestone at the base of this series is a coarse limestone which is called a dolomite because it is composed of both calcium and magnesium carbonates. It is readily soluble in the surface waters and therefore is represented by clay residue from its impurities in most places. As one of the classes of manganese deposits is closely associated with this rock or formation, the name Shady dolomite, by which it is generally known, will be used here. Next above is a clayey shale formation in which hard purple shale and calcareous shale and sandstone generally occur and because of their greater resistance to weathering than the adjacent limestones they form low hills. This formation also carries manganese deposits in certain parts of the State. It is known as the Watauga shale.

The limestones directly above the Watauga shale contain chert or flint nodules and these masses abound in the soil derived from this lime rock. As the chert masses are in many places seamed with manganese oxide and fragments of this manganese ore occur in the residual soil from the limestone, this formation will be referred to by its long-established name, Knox dolomite.

The upper beds of the limestone series are generally a gray to reddish crystalline limestone in East Tennessee. Some of the beds are of the proper texture to be called a marble and constitute the Tennessee marble for which the vicinity of Knoxville is noted. This crystalline limestone and other associated beds, some of which are shaly, argillaceous, and nodular to pure, blue, dense limestone, has been called the Chickamauga limestone and the marble layers are called Holston marble. Some of the best deposits of manganese occur at the contact of the marble with overlying red sandy limestone which weathers to porous sandstone and is known as Tellico sandstone. These formation names will therefore be used in the description of the ore deposits.

In the southwestern part of East Tennessee the limestone series is overlain by a thin black shale and this by white chert or cherty limestone. The latter contains in places manganese deposits, and its name, Fort Payne chert, will be used in the description of the deposits. In the table on page 26 the various formations are given in their proper order and the characteristics of each are briefly described.

Generalized Table of Geologic Formations in Areas Where Manganese Occurs in East Tennessee.

System	Formation		Character of Rocks.
Carboniferous	Fort Payne chert		Thin bedded chert.
Devonian	Chattanooga shale		Black shale.
Silurian	"Rockwood" formation		Sandstone and shale.
Ordovician	Sevier shale		Yellow argillaceous shale and calcareous shale.
	Tellico sandstone	Moccasin limestone	Red sandstone and sandy limestone.
	Athens shale (in places)		Fissile shale.
	Holston marble (in Chickamauga limestone)		Buff to red marble.
	Chickamauga limestone		White crystalline limestone, blue limestone, and shaly limestone.
Ordovician and Cambrian	Knox dolomite		Massive dolomite and limestone, with nodular chert.
Cambrian[1]	Nolichucky shale		Shale and thin bedded limestone banded with sandy layers.
	Honaker limestone	Maryville limestone Rogersville shale Rutledge limestone	Limestone, dolomite, and thin shales.
	Watauga shale	Rome formation	Purple sandy shale and sandstone, with some limestone.
	Shady dolomite		Light dolomite, largely coarse granular.
	Erwin quartzite	Hesse quartzite	Hard white quartzite, containing scolithus tubes, and some shale.

[1]The upper part of this section represents conditions in the area west of Cleveland in Southeastern Tennessee, where the black shale (Chattanooga) is believed by some, including the writers, to be of carboniferous age. In northeastern Tennessee other formations of Silurian, Devonian, and Carboniferous ages lie above the Sevier shale, but are not referred to in this report.

System.	Formation		Character of Rocks
Cambrian	Hampton shale	Murray slate Nebo quartzite Nichols slate	Dark shale, slate, and quartzite.
	Unicoi formation	Cochran conglomerate Hiwassee slate Snowbird formation	Coarse arkosic sandstone, quartzite, conglomerate, and slate.
Pre-Cambrian	Granite and schist		Granite and schist.

Type of Deposits.

There are many kinds of manganese ore deposits in eastern Tennessee, but they may be grouped under eight types, depending chiefly on the groups of rocks with which the deposits are associated. These will be briefly described in the general order of the frequency of their occurrence, as follows:

1. Deposits in Shady dolomite.
2. Deposits in Watauga shale.
3. Deposits in Knox dolomite.
4. Deposits on Holston marble.
5. Deposits in Fort Payne chert.
6. Deposits along fault planes.
7. Deposits in terraced stream gravels.
8. Carbonate ores in the older dolomite.

The distribution of the areas in which each type of deposit prevails in East Tennessee is shown in figure 4. The fault and terraced stream gravel types cannot be shown, as they do not occur in prescribed areas.

STATE OF TENNESSEE
STATE GEOLOGICAL SURVEY
Wilbur A. Nelson, State Geologist

UNITED STATES GEOLOGICAL SURVEY
George Otis Smith, Director

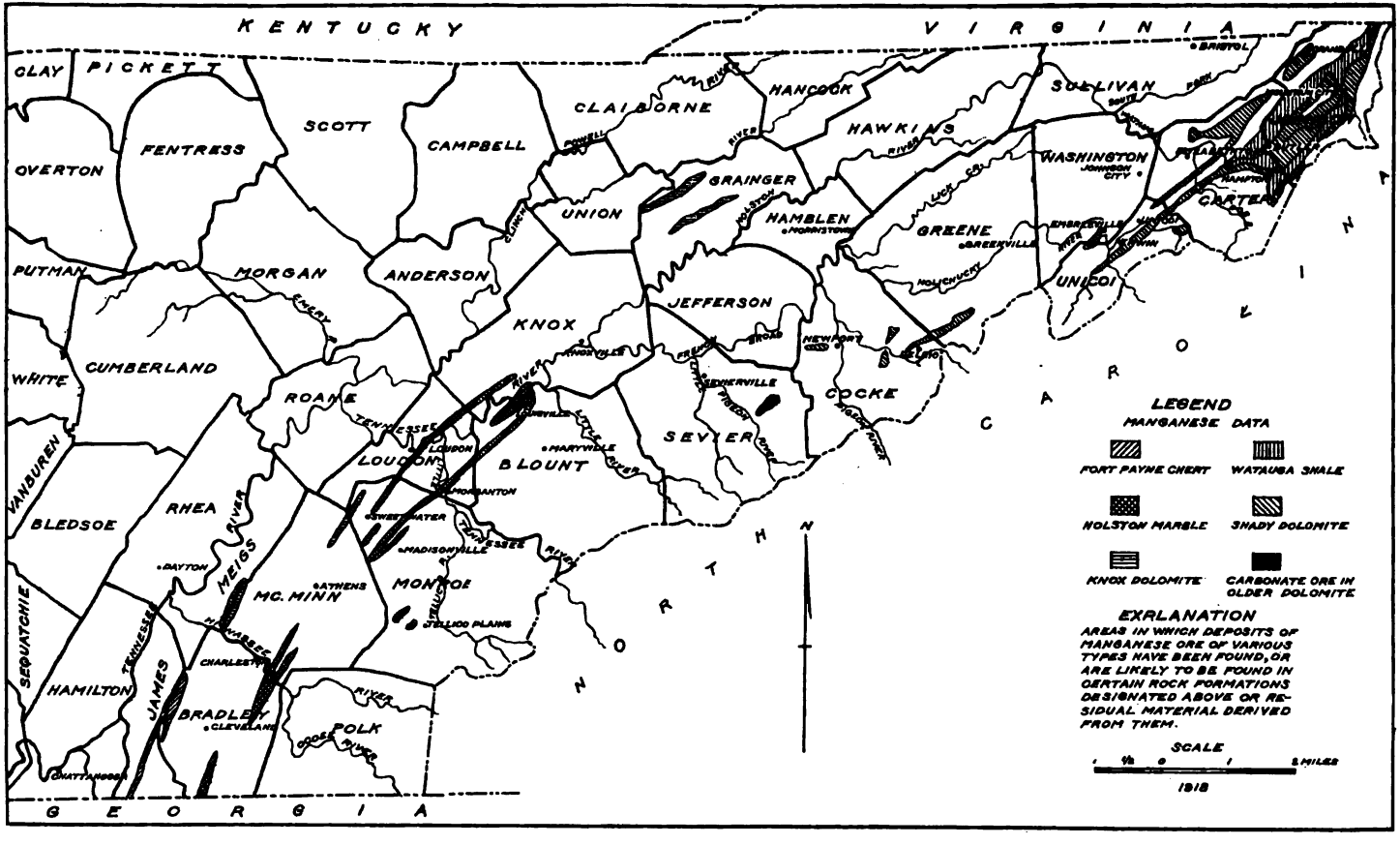

FIGURE 4. Map of East Tennessee showing distribution of areas in which certain types of manganese deposit occur.

DEPOSITS IN SHADY DOLOMITE.

Throughout Virginia and parts of eastern Tennessee manganese ores occur in the clays which are residual from the impure basal limestones of the Shady dolomite. Between the typical dolomite of the Shady and the uppermost white quartzite beds of the underlying Erwin are transition beds of various kinds, which, because they are partly soluble or readily weather to clay and soil, are generally classed with the Shady dolomite, which also usually weathers to clay. These transition beds are therefore seldom exposed, but in Stony Creek and Shady valleys in northeastern Tennessee and in portions of southwestern Virginia their character is well shown. They are about 100 feet thick and embrace yellow finely laminated clays, which evidently were originally calcareous shale, and shaly arkosic sandstones, some stained red and purple with iron, others of a greenish color due to contained glauconite grains. At the top are rusty, coarse grits of rounded quartz grains, from which the former calcareous cement has been mostly dissolved, leaving the bed a porous layer or a loosely coherent mass of quartz grains, in many places stained black with manganese or rusty with iron.

The manganese ores in the Shady dolomite are composed largely of masses of psilomelane scattered through the residual clay. Many of these masses are of irregular shape, but some are botryoidal and nodular. In some places cavities in the psilomelane are lined with crystalline manganite. Rarely the manganite forms distinct balls and rounded masses of radiate needle ore. Nearly all the ore must be washed to free it from the sticky clay. The ore when present in the adjacent quartzite must be crushed and the quartzite separated by washing or some other process. The ore that generally occurs in the wash overlying the residual clay is usually both ferruginous and highly siliceous, as it contains grains and pebbles of quartz that cannot readily be removed. Much of this must be rejected as of too low grade.

The manganese deposits associated with the Shady dolomite lie in clay derived from impure laminated limestones directly overlying the transition beds, and it is believed that the ore-bearing solutions came from these transition beds, in which manganese was originally disseminated with the other heterogeneous sedimentary materials. As described in more detail in previous reports on the manganese deposits

of Virginia[1] the ore in most cases accumulated on the edges of the inclined beds at the base of the Shady dolomite which outcrops along the foot of ridges composed of Erwin quartzite which in turn dips beneath the Shady dolomite. Where the rocks are folded into gentle troughs parallel to the foot of the ridges so that the descending ore-forming solutions following the surface of less impervious layers were concentrated along their bottom, the deposits of manganese ore in the overlying clays are generally of greater thickness and value. Such is the case in the noted Crimora mine near Basic, Va. The quartzite beds in the adjacent Erwin quartzite are in places seamed and brecciated and the particles cemented together with manganese oxide. Some of the quartzite is also replaced by the ore. Although such deposits should properly be classed by themselves, they are of so little value in Tennessee and are so closely associated with the deposits in the Shady dolomite that the few that occur will be described under this type.

Manganese deposits in the Shady dolomite occur at many places along the west foot of the Appalachian Mountains in East Tennessee and on both sides of coves and re-entrant valleys within the mountains where the Shady dolomite lies at the foot of the steep slope of the Erwin quartzite ridges in the position just described. The deposits are, of course not continuous along this dolomite-quartzite contact as their accumulation in this position depends on the quantity of the manganese minerals originally present in the adjacent rocks, on the steepness of dip of the rocks, on the extent of decay of the bedrock, on the slope of the surface of the bedrock or its residual clay and the cover of wash on that surface through which the ore-bearing solutions could percolate slowly, for the ore is deposited more freely where the solutions move slowly. They are of course not present where the rocks have been faulted so that the dolomite is absent or is deeply buried.

In Shady Valley, Johnson County, the Erwin quartzite dips gently beneath the Shady dolomite from both Holston Mountain on the west and Iron Mountain on the east and the favorable conditions are evi-

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[1]Hewett, D. F., Some manganese mines in Virginia and Maryland, U. S. Geol. Survey Bull. 640, pp. 37-71, 1916; Hewett, D. F., Stose, G. W., Katz, F. J., and Miser, H. D., Possibilities for manganese ore on certain undeveloped tracts in Shenandoah Valley, Va., U. S. Geol. Survey Bull. 660, pp. 271-296, 1918; and a forthcoming report of the Geol. Survey of Va. by the same authors on The Manganese deposits along the foot of the Blue Ridge, Va.

denced by deposits of manganese on both sides of the valley, several of which have been prospected and mined. The dips are more gentle and therefore conditions more favorable for the deposition of ore on the western side. This basin is terminated at the north and south by the gentle rising of the strata in these directions. Minor longitudinal folding at the north end of the basin divides it into two troughs in the vicinity of Crandull. At these rising ends of the trough, conditions are most favorable for commercial deposits.

Southwest of Shady Valley, in the valley of Stony Creek, Carter County, which also lies between Holston and Iron mountains, similar geologic conditions prevail, but the deposits that have been discovered there are not so rich as those in Shady Valley. The ore-bearing formation extends to Keesburg on the west side of the valley and to Blue Springs on the east side of the valley. This eastern belt of the Shady dolomite follows along the northwest foot of Iron Mountain to Valley Forge and thence along the foot of Gap Creek Mountain and Little Mountain, the southwestward continuation of Iron Mountain, nearly to Unicoi, where it is terminated by a fault.

On the northwest side of Stone Mountain and on the slopes of the outlying ridges of Erwin quartzite in Johnson County, favorable geologic relations occur at many places, but most of the deposits of this type that have there been explored are small. Southwestward the deposits along the belt increase in value and have been mined at several places at the northwest foot of Stone Mountain in Carter and Unicoi counties from Cardens Bluff to Erwin, beyond which the Shady dolomite is cut out by faulting. In Bumpass Cove, a limestone valley shut in by mountains, the geologic relations are favorable only along the northwest side where the Erwin quartzite dips southeast under the Shady dolomite of the Cove.

Due to great faulting along the northwest front of the Appalachian Mountains from Erwin southwest to the State boundary the Shady dolomite and Erwin quartzite do not occur in their normal relations at the foot of the mountains. On the south side of Meadow Creek Mountains in the southern part of Cocke and Greene counties, the geologic conditions are locally favorable for the occurrence of ore but the few deposits that have been prospected there and at the east end of the mountain are apparently small. Again on the north end of English Mountain in Sevier County, deposits are being mined at the

base of the Shady dolomite, where geologic conditions are again locally favorable.

DEPOSITS IN WATAUGA SHALE.

In the extreme northeastern part of Tennessee, as in the adjoining southwestern part of Virginia, deposits of manganese ore occur in the soft disintegrated beds of Watauga shale at certain places. Such deposits have been worked in Johnson County northeast of Mountain City, and in Doe Valley southwest of Mountain City, and have been prospected and mined on a small scale in both Johnson and Carter counties near Butler. The ore is largely psilomelane, but much of it is fine needle ore, manganite changing to pyrolusite. It fills pockets in the yellow clay and replaces porous, disintegrated yellow sandstone.

As the structural relations of the deposits in the Watauga shale have not been fully determined, little can be said at this time as to where other workable deposits of this type may be found. Those deposits which have been studied seem to be associated with basins or troughs in the shale. Therefore the central part of Doe Valley, which is a broad syncline, and the region south and west of Butler, where synclinal or trough-shaped folds occur, both of which are areas in which manganese ore has already been found in commercial quantities, are apparently the most favorable places to search for ore.

DEPOSITS IN KNOX DOLOMITE.

The chert in the Knox dolomite is stained black with manganese oxide at many places. Some of the chert masses have been broken up into fragments which are cemented together by manganese oxide and in part replaced by the ore, so that some masses of ore of large size may be formed in this manner. The chert and ore are set free by the weathering of the limestone and are found in the residual clay soil on the slopes of chert hills. Most of the ore in the chert is hard psilomelane, and some of the residual masses are very pure heavy ore with crystalline manganite in crevices. Nodular psilomelane (nut and grape ore) coated with red iron oxide also occur in the associated clay.

Ore in the Knox dolomite has been found throughout the valley of East Tennessee and it has been prospected at many places. One is apt to be misled by finding one or two large chunks of ore, often of high grade, and conclude that a workable deposit exists. Few deposits of promise have been opened in ore of this type, and such as are being mined, as the one near Rutledge, are at the contact of the

Knox dolomite and a shale, so that conditions are somewhat favorable for the accumulation of ore.

DEPOSITS ON THE HOLSTON MARBLE.

Marble beds, called the Holston marble, occur in the Chickamauga limestone at most places in East Tennessee but are not generally accompanied by manganese ore. Where the marble is thin and is overlain by red calcareous sandstone, called Tellico sandstone, high grade iron ore and some manganese ore generally occur. This is believed to be due to the irregular relations between the Tellico sandstone and Holston marble representing a break in the process of sedimentation between the deposition of lime silt and the overlying sand, at which time land conditions probably prevailed. (See Fig. 7a.) Such a break in sedimentation is called an unconformity, and such conditions are generally accompanied by the deposition of unusual material, the waste from the weathering of older sedimentary rocks that formed the old land surface. In this instance iron and manganese minerals were probably disseminated in the unconformable basal Tellico sediments and when the Tellico sandstone weathered and the soluble lime carbonate was dissolved out of it near the surface, the iron and manganese were concentrated by solution and redeposition in certain layers and formed beds of ore. Some of these beds of ore are found interbedded with the sedimentary rock and the impressions of the fossils of the original rock are preserved in the ore, but most of the ore is in loose masses in the residual sandy clay resting on the marble. The manganese ore is very pure psilomelane and crystalline manganite, and in most cases can be hand picked and shipped without washing. The associated iron ore is a high grade red hematite, including both fossil ore and fine shiny-pebble ore.

The only known occurrences of manganese ore in the Holston marble are in the vicinity of Sweetwater, Cleveland, and Louisville. Several belts of marble overlain by the Tellico sandstone occur east and south of Knoxville and small pieces of ore are found in the overlying soil, but only in a few places, chiefly in the vicinity of Sweetwater, have deposits of commercial value thus far been developed. In Monroe County between Sweetwater and Philadelphia several rich deposits have been opened, and on another belt 6 miles to the east other deposits have been worked in Monroe and Loudon counties. Further search along these zones of contact of the Holston marble and

Tellico standstone is urged, as other similar deposits are likely to occur. The Sweetwater belt is cut off by a fault at Sweetwater but reappears 6 miles south of Cleveland where it is again ore bearing and the ore belt continues out of the State into Georgia.

DEPOSITS IN THE FORT PAYNE CHERT.

The Fort Payne chert, where it makes low ridges in the southern part of the State, is impregnated in places with manganese oxide. The ore fills cracks and crevices in the chert ledges and in part replaces the chert itself, so that masses of ore of considerable size occur. On the slopes of the ridges the fragments of chert cover the surface and with them are accumulated the ore which had been set free by the weathering of the chert. Some of the manganese oxide also has been redeposited in the clay and loose material on the slope and some of these deposits are of workable size. The ore in the chert is bright psilomelane, and most of the ore in the residual clay is also psilomelane, in part nodular. At Walnut Grove, in Alabama, very rich needle ore and soft pyrolusite have been mined in residual clays at this horizon, but none have been observed in Tennessee.

Deposits in the Fort Payne chert have been mined and prospected in the White Oak Mountains west of Cleveland, and the same geologic conditions continue along the southeast side of these mountains into Georgia, and other deposits may be discovered in this undeveloped territory.

DEPOSITS ALONG FAULT PLANES.

Iron and manganese ores are deposited in the rocks adjacent to fault planes. Minerals scattered through the rocks are dissolved by circulating waters, which then rise along the fault planes, and the ores are deposited in brecciated zones, porous strata, or clays at or near the surface. Many of the deposits in the ore-bearing zones previously described may have been in part due to circulation of solutions along fault or joint planes, but only those are here referred to which are known to have been largely determined by this process. The character of the ore is controlled largely by the associated rocks.

There are many bedding or strike faults in East Tennessee whose outcrops follow the general trend of the rocks, and many are marked at the surface by belts of siliceous iron ore and ferruginous chert. Workable bodies of iron ore on fault planes have been mined at several places in the past and a few prospects of manganese ore are located

on faults. The only manganese mine known to be located on a fault in East Tennessee is at Taylor Valley northeast of Mountain City. Other deposits of value may exist and can be sought by prospecting along the faults which are so common in the area, but the likelihood of finding workable deposits is not encouraging.

DEPOSITS IN TERRACED STREAM GRAVELS.

Nearly all manganese deposits include in their upper part a layer of surficial clay and mountain wash in which some ore is deposited. Only those deposits which occur in gravels and sand of stream origin and which do not continue down into the underlying bed-rock or its residual clays are included under this head in this report. The ore is apt to be siliceous and include fragments and grains of quartz. The ore at the Silver Lake mine north of Mountain City is also ferruginous.

The only known deposit of manganese ore in stream gravel in East Tennessee is in gravel and sand on a bench about 50 feet above the present drainage near Silver Lake, northeast of Mountain City. Such deposits must be derived from some nearby source of ore solutions and may be looked for in stream gravels on old terraces near known deposits of other types.

CARBONATE ORES IN OLDER DOLOMITE.

Carbonate of manganese has been found in dolomite in the old slates interbedded in the quartzites of the Appalachian Mountains at one place in East Tennessee, but may occur elsewhere under similar conditions. It occurs in lenticular beds in the contact of the dolomite and the inclosing slate, and is undoubtedly a replacement of calcareous rock along this zone. Manganese minerals were probably originally disseminated in either the dolomite or slate and were concentrated by waters circulating along fracture planes at the contact while the rocks were still below the zone of surface oxidation. The beds now stand vertically and the upper ends of the ore layers are altered to psilomelane and manganiferous iron in manganiferous clay. These oxide ores are found at the surface and only after mining to a depth of 6 to 10 feet was the carbonate ore encountered. The carbonate ore looks like a dolomite or limestone and is distinguished only by its weight and by its discoloration on exposing at the surface, a thin film of dark-gray oxide quickly coating it. The ore contains about 35 per cent manganese, but since it is a carbonate it is a flux

in itself and when mixed with oxide ores reduces the amount of limestone necessary in the charge. It therefore has a higher value to smelters than the manganese content would indicate, and the price it commands should be proportionately larger.

The ore has been found at only one place in East Tennessee, that is in Sevier County, 13 miles east of Sevierville, but it may be expected at other places in the heart of the Appalachian Mountains where the older slates carry a similar body of dolomite. Such dolomite bands, especially those in the near vicinity, should be searched closely for other deposits.

Description of Mines and Prospects.

A complete description of the manganese mines and prospects in East Tennessee will be published in a later number of this magazine. Only one mine or prospect of each type will be here described, followed by a tabular list of all the mines and prospects that have been visited or have been authentically reported.

NEWPORT MINE.

Deposit in Shady Dolomite.

The Newport mine, formerly known also as the Yellow Springs mine and the Carson Springs mine, is in Cocke County at the northeast end of English Mountain, five miles southwest of Newport. The deposit was discovered in 1883 by George Francis, who is said to have mined and shipped for George Cole 120 tons of unwashed nodular manganese ore from a small pit at the mouth of the present working. Beyond this rich body the ore occurred only in sporadic small pockets but they finally led to the discovery of the deposit now being mined.

The property is owned by the Sant estate with headquarters at East Liverpool, Ohio. The mine is being operated by the Newport Manganese Corporation of Newport, Tenn., of which the Southern Manganese Corporation of Birmingham holds a controlling interest. The composition of the ore that has been shipped is said to have been approximately 37 per cent manganese, 8 per cent iron, and 12 per cent silica. In 1917 the mine shipped 120 tons of ore which averaged more than 40 per cent in manganese, part of the shipment going to E. E. Marshall, Philadelphia, Pa., and part to the Southern

Manganese Corporation, Anniston, Ala. The ore brought about $25 a ton.

The mine is on the northeast terminal slope of English Mountain where it descends into the valley of Pigeon River. It is located at the edge of a bench on the mountain slope, 1,700 to 1,750 feet in altitude. The floor of the main pit of the mine is at 1,680 feet elevation and several prospect pits, both old and recent, at approximately this same elevation show fair indications of ore extending interruptedly nearly one-fourth mile southwest of the mine. Both nodular and stalactitic forms of manganese ore are embedded in the clay and wash of this bench.

The deposit occurs in the Shady dolomite about 100 feet above the Erwin quartzite. The structure at the mine is monoclinal, the quartzite beds of the mountain only 200 feet away dipping 75° N. toward the valley. The clays in the mine show similar bedding dipping 60° toward the valley.

The main pit, which trends nearly east and west, is approximately 150 feet long by 50 feet wide, and 50 feet deep at the face. It is excavated chiefly in reddish and brownish clay derived from the Shady dolomite and transitional beds, although pure white sand or sand clay are also conspicuous. The clay of the south or foot wall is chiefly white and very siliceous, containing rounded disintegrated fragments of sandstone or quartzite, and was probably derived from a sandstone or sandy limestone. It is firm and compact, so that this wall of the pit stands well. The clay of the north or hanging wall is sticky and chiefly yellow, and was probably derived from limestone or dolomite. The ore is contained in a layer about six feet wide of banded and mixed red, brown, lavender, bluish, and white sandy clay and sticky yellow clay, which dips 60° N. The ore is sporadically embedded in this clay in the form of grains, nodules, and lumps, some as large as three feet in diameter. It is evidently in a brecciated layer at the top of sandy beds in the Shady dolomite, which has been enriched probably by the leaching of the ore from the porous sand below, now left white, and its redeposition in the beds next to the impervious clay roof.

The overburden, which consists chiefly of red clay and quartzite boulders, varies from 1 to 10 feet in thickness. In places, as shown locally in the north bank of the pit, the ore extends nearly to the surface.

As the ore is mined it is shoveled into the head of a flume 875 feet long to which water is pumped, and is conveyed to a double log washer 260 feet below the mine. In its passage down the flume, or launder, much of the ore is freed from the clay by the swift current, but a small per cent of the ore is lost by adhering to the sticky clay which is allowed to go in with the ore and is rolled into balls.

On leaving the trommel after passing through the washer, the ore which does not pass through the one-eighth inch mesh sieve is conveyed by carrier belt to the bin and is hand picked en route by boys and women. About 30 per cent of the washed ore passes through the screen and constitutes what is known as "fines." It contains too much silica to be shipped direct and must be jigged to further free it from silica.

DOE VALLEY MINE.

Deposit in Watauga Shale.

The Doe Valley mine, also called Fritz mine, is in Johnson County, seven miles southwest of Mountain City and about the same distance north of Mouth of Doe, both on the Tennessee division of the Virginia and Southwestern Railroad. It is on the farm of Mr. Fritz of Mountain City, and is being operated by the East Tennessee Mining Company, also of Mountain City, in which the Southern Manganese Corporation of Birmingham, Ala., holds an interest.

Sixty-two tons of high-grade manganese ore averaging more than 50 per cent in manganese were shipped in 1917 to the Southern Manganese Corporation at Anniston, Ala., and in 1918, up to May 24, 200 tons of similar ore had been shipped and forty tons more were ready for shipment.

The mine is located on a hill 150 feet above Doe Creek on the northwest side of Doe Valley. The hill is part of a dissected upland plain which forms a sort of upper valley floor about 2,500 feet in altitude into which the stream valleys are sunk.

The deposits occur in disintegrated Watauga shale, the ore largely replacing brecciated sandstone and soft weathered calcareous shale or yellow laminated clay. The overburden is about three feet of red clay and dark surface soil. The ore occurs largely in irregular zones or bands more or less comformable with the bedding of the rocks, which dip 40° to 70° southeast. Abrupt change in dip, minor folding

and puckering, and slickensiding along the bedding planes are evidences that the rocks have been strongly compressed.

The deposits are opened by an open cut near the top of the hill, which trends N. 70° E. parallel with the strike of the rocks, and has a length of 120 feet, the width of the floor and height of the face being each 30 feet. A new entry about 70 feet long and 15 feet or more deep at the face is being driven in from the west at a lower level to tap the ore layer below the floor of the main opening. The pit is chiefly in soft yellowish laminated clay, or weathered shale, with which are interbedded layers of light-brown porous sandstone, one to three feet thick, generally brecciated and deeply disintegrated. Cutting across the bedding nearly at right angles are zones a foot or two wide of breccia made up largely of hard purple shale fragments, which resemble subterranean channel fillings. (See Fig. 5.) They are of ir-

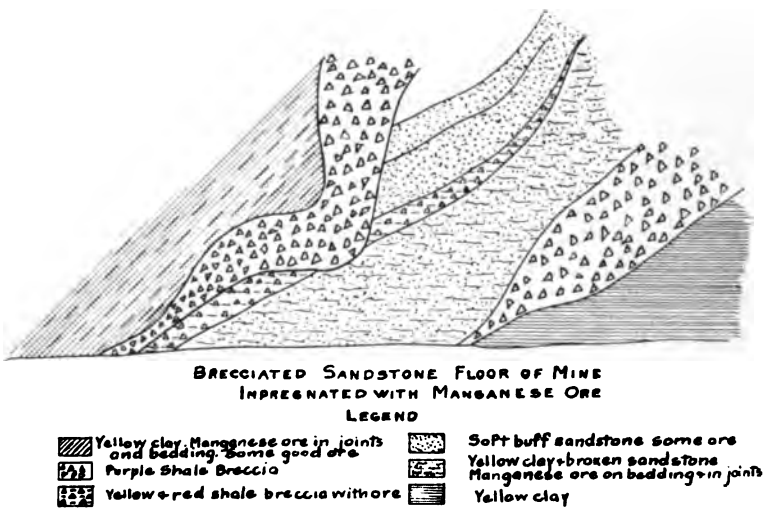
BRECCIATED SANDSTONE FLOOR OF MINE
IMPREGNATED WITH MANGANESE ORE
LEGEND
Yellow clay. Manganese ore in joints and bedding. Some good ore
Purple Shale Breccia
Yellow & red shale breccia with ore
Soft buff sandstone some ore
Yellow clay & broken sandstone Manganese ore on bedding & in joints
Yellow clay

FIGURE 5. Sketch of right wall of entry to pit of Fritz mine showing irregular bands of purple shale breccia crossing the bedding.

regular shape, and in depth turn along the bedding planes, passing between laminated clay and brecciated sandstone layers. They seem to represent subterranean solution channels which connected with channels in the porous standstone beds. The brecciation of the sandstone and the irregular folding and puckering of the laminated shale were probably brought about by the settling and partial caving in

of the rocks over the channels. The deep weathering and the penetration of the surface waters to this and greater depths occurred long ages ago when the tops of this hill and of the neighboring flat-topped hills were part of the general floor of the valley. This was before the present streams cut their valleys 150 feet deep to their present positions.

The ore consists chiefly of psilomelane and wad. A little manganite and pyrolusite are probably present. The manganese is distributed more or less throughout the rocks from near the surface to below the bottom of the cut, for its lower limit has not yet been reached. The ore, however, favors the arenaceous layers interbedded in the clayey shale, and is mostly contained in four such beds or zones, each from one to three feet in thickness. The ore is irregularly distributed in these arenaceous zones. It occurs to a considerable extent in seams ranging up to three inches in width which follow both the bedding of the rocks and the joints at right angles to it. Some of the seams are composed of psilomelane having stalactitic or comb structures perpendicular to their walls which meet and interlock at the center, showing deposition or replacement to have taken place simultaneously on both sides of the cavities. Many of the stalactites are coated with a brown velvety film, probably pyrolusite or some other manganese oxide. Some stalactitic forms are several inches in length and somewhat radiate, forming trumpet-shaped clusters. (See Fig. 3b.) At the junction of two planes at right angles, the stalactitic structures miter with each other, showing that the stems are perpendicular to the walls and not truly stalactites—i. e., pendant vertically from a roof. Some of the ore masses are aggregates of alternate layers of stalactitic structure and amorphous material about two inches thick of dark-brown dense wad or manganiferous clay of light weight. Even the stalactitic psilomelane weathers dull and in some cases disintegrates into light powdery fragments. Some of the forms are elongated mammillary, or nipple-shaped, with surfaces that have in part a bright black metallic luster.

The ore is removed from the mine by a short tram to a flume, and thence to a two-log washer at the foot of the hill, where it is treated and the products sorted into bins. Much of the ore is lump, over three inches in size, but the fines are also saved. It is estimated that the proportion of ore saved to material washed is about 1 to 15 or 20.

The material excavated, taken as a whole, is said to yield a ton of washed ore for each fifty cubic yards of ground excavated.

Prospect pits along the trench of the ore on the top of the hill indicate a total length of the deposit in the direction of at least 350 feet and a width of about 150 feet. Its known depth to the bottom of the deepest workings is about sixty feet, so that a considerable body of ore-bearing ground is still in sight.

RUTLEDGE MINE.

Deposit in Knox Dolomite.

The Rutledge mine is two miles southeast of Rutledge, Grainger County, on a branch of the Southern Railway between Knoxville and Morristown. It is on the farm of J. H. Lowe, of Rutledge, and is being operated by J. S. Swann of Knoxville. No ore had been shipped at the time of the visit but about 100 tons were on the dump, 30 tons of which had recently been mined. The ore is reported to average 33 per cent in manganese. It contains considerable silica, which is mostly too fine to appear as grains, and much iron.

The mine is on the top of a prominent hill 650 feet above the railroad at Rutledge, to which place the ore must be hauled. The deposit occurs in the basal part of the Knox dolomite at or close to its contact with the underlying shale, which is presumably Nolichucky. The shale dips very gently southeastward into the hill, the structure being apparently monoclinal. However, relations at the mine and of the rocks on the slope below the mine are such as to leave doubt as to this structure and it is possible that the Knox is overthrust on the shale and that the shale is younger than the Nolichucky. Further study of the surrounding region is necessary to determine this point.

The mine consists of an open cut 150 feet long and 20 feet high along the northwest face of the hill. Several vertical bands of ore cross the face of the cut. The northern band is composed largely of botryoidal masses and nodules of black psilomelane more or less dulled by impurities and covered with iron oxide up to one-half inch in thickness, the outer coating being generally a brilliant red oxide. (See Fig. 6.) These are embedded in sticky yellow clay. A middle band is composed largely of a thick body of heavy psilomelane ore inclosed in dense yellow clay. At the south end of the cut yellow clay is laminated by manganese stains and thin layers of ore which dip

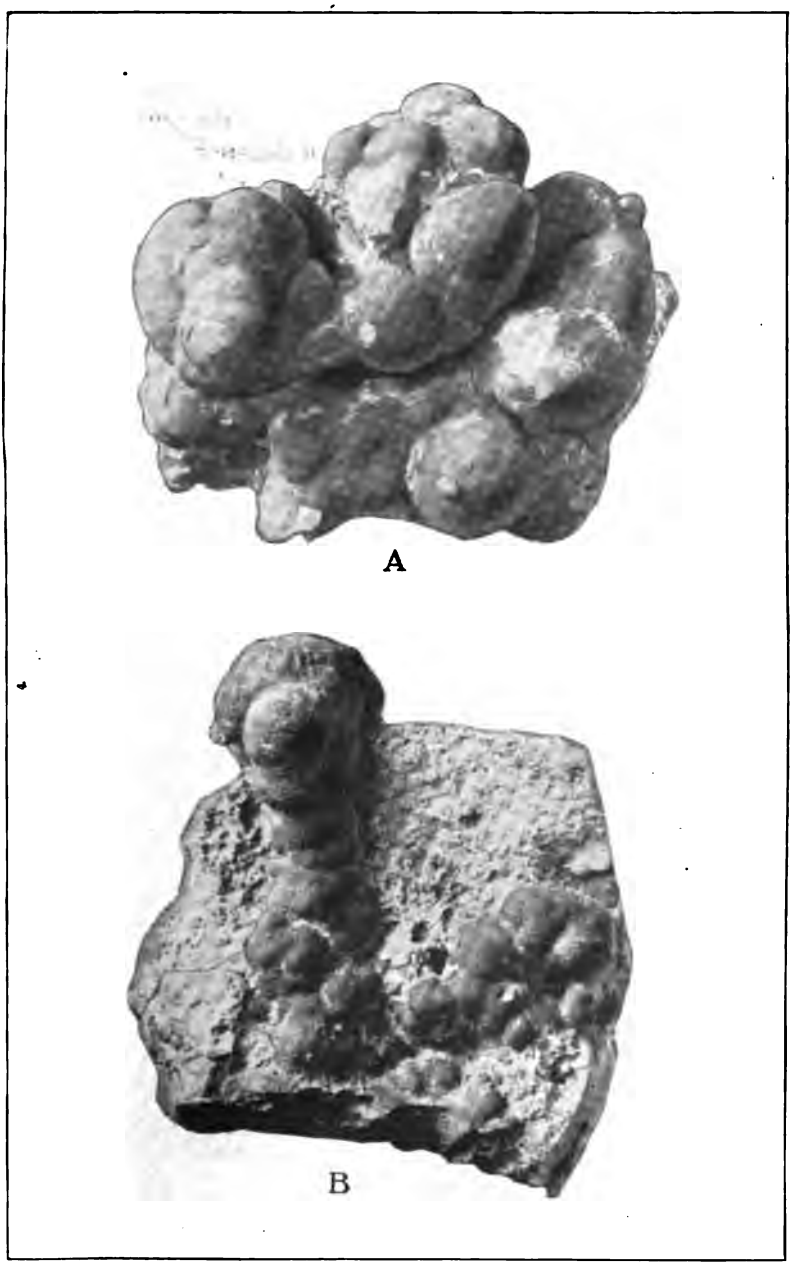

FIGURE 6. Nodular psilomelane ore coated with brilliant red oxide of iron. Rutledge mine, Grainger County. b. Manganese nodule in chert matrix.

10° to 30° NW apparently following the original bedding. It also contains chert partly replaced by manganese. The clays throughout the trench seem to be residual from weathered Knox dolomite, the vertical bands of ore also probably following the original bedding. The discordance of this supposed bedding with that of the underlying shale is one of the evidences in favor of faulting. There is a thin overburden of sandstone and chert wash at the top of the cut and the ore in it contains sand grains and more iron than that in the residual clay below. The top of the hill above the cut is covered with chert fragments in which considerable good manganese ore is present.

As the ore in the cut embedded in red and yellow sticky clay which fills the crevices and indentations in the botryoidal surfaces, it will require thorough washing to fit it for shipment. The problem of procuring an adequate water supply for this purpose has not been settled. The ore is the chert of the overburden and on the surface will require crushing and hand picking to remove the silica.

Although this mine is in Knox dolomite and consists in part of chert replaced by manganese ore, it is not typical of deposits in the Knox as it is at or close to a shale contact which may also be a fault contact. Most other deposits in the chert of the Knox, such, for instance, as that at McDonald's prospect southeast of Sweetwater, can be simply described as consisting of fragments of broken chert cemented together, and more or less replaced, by manganese ore which are scattered loosely in yellow to reddish residual clay on a chert hill in the midst of a broad belt of Knox dolomite. No original structure can be observed in the clay and therefore the relations of the ore to the rock formations can not be determined. The amount of manganese ore is generally so small and the ore masses though of high grade are so scattered that none of these deposits have proved of commercial value.

HAMBRIGHT MINE.

Deposit on Holston Marble.

The Hambright mine is in Bradley County, eight miles south of Cleveland and two miles northeast of Marble Switch on the Southern Railroad, to which point the ore is hauled. The property is owned by Mr. Hambright of Cleveland and the mine is being operated by Fitzgerald and Lanskey of Chicago, with office at Cleveland, who recently acquired the lease from Ryan and Thomason. Up to July 1st,

FIGURE 7. a, Sandy laminated limestone of the Tellico sandstone resting unconformably on Holston marble in which there is a thin seam of psilomelane (P). Pit of D. A. M. mine, Bradley County.

b, Pit of the Silver Lake mine, Johnson County. Large boulders from the stream gravel are gathered in piles at the face of cuts.

1918, the mine had shipped this year 120 tons of ore averaging more than 50 per cent in manganese, and about 50 tons of similar high grade ore lay on the dump. The ore was shipped to the Tennessee Coal, Iron and Railroad Co., Birmingham, Ala., and to the Carnegie Steel Co., Pittsburgh. The ore is hand picked and is shipped without washing.

The mine is in an open field on a gently rolling hilltop that trends northeastward and forms a terrace between the valley and a higher line of hills to the east.

The deposits occur chiefly at the contact of the Holston marble and the unconformably overlying Tellico sandstone. The structure in monoclinal, the rocks dipping from 25° to 80° SE. The marble is dark gray and crystalline, and in the northern end of the pit is well shown dipping 25° S and SE beneath the deposits. Southward in the pit the residual clay from the decomposed rocks dips 80° SE. The marble is sparingly seamed with brown ferruginous arenaceous material, in places changed or enriched to hematite.

The overlying beds of the Tellico sandstone, which are reddish limestones, contain grains of glassy sand, which are segregated more plentifully in thin layers so that on weathering the rock first becomes closely banded or ribbed, then a porous friable red sandstone, and finally red sand or sandy clay. That the sandy limestone is unconformable on the marble is clearly shown in pits of the adjacent D. A. M. mine, illustrated in Fig. 7. The iron and manganese set free by the weathering were redeposited in seams or in certain porous layers in the underlying marble (see Fig. 8) and were concentrated in places into a definite bed of ore at the contact of the marble and sandstone. (See Fig. 9.) The ore bed in part retains the original granular texture of the porous sandstone, and imprints of the fossils originally contained in the rock are still preserved. Glossy grains of quartz are contained in beds transitional from the sandstone to the solid psilomelane. As the inclosing rocks weathered away, fragments of this ore were scattered through the residual clay and sand, and are now found as loose blocky fragments.

The main opening is a pit 500 feet in length which trends N 30° E. (See Fig. 8.) The pit has a width of about 200 feet in its widest part near the north end, and a maximum depth of 30 feet. The ore occurs in the pit as irregular blocky or slabby masses and fragments

several inches thick embedded in dark-red sandy clay, and also as a nearly vertical bed a foot or more thick which roughly follows the contact of the marble and sandstone. (See Fig. 9.) This nearly vertical bed of ore crops at intervals along the bottom of the 500-foot pit, in red sandy clay, which represents the Tellico, generally forming the southeast or hanging wall, and red and yellow blotched clay,

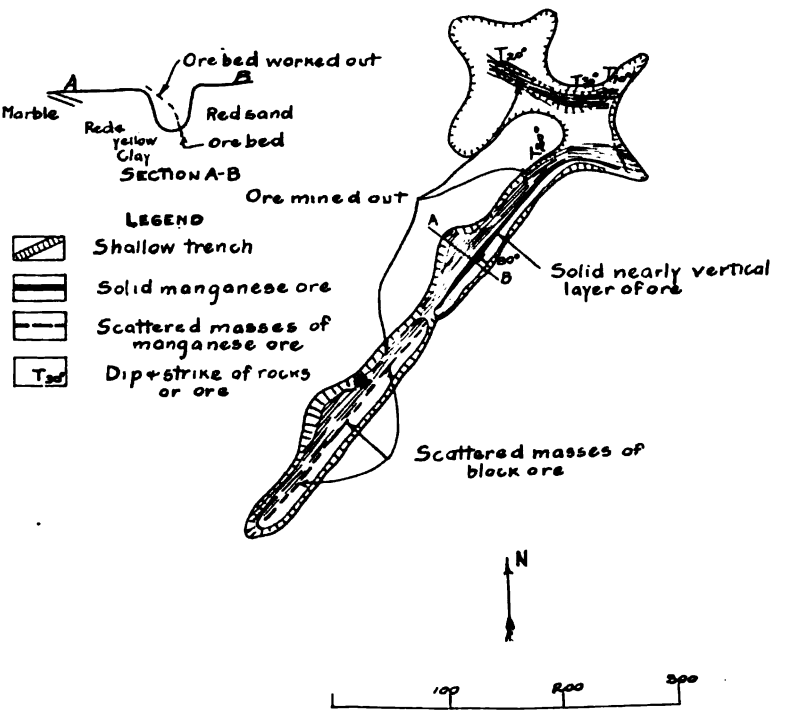

FIGURE 8. Rough sketch of the plan of Hambright mine pit, and cross section showing probable relation of ore.

which represents the Holston, forming the northwest or foot wall. This nearly vertical bed is said by the miners to have formerly flattened out toward the top of the excavation so as to dip gently southeast, in conformity with the bedding of the marble to the northwest, which accounts for the widening of the trench at the top in most places. Near the north end of the pit, the ore bed turns sharply eastward but is repeated again just beyond in the wider part of the pit by either sharp folding or faulting. Other masses or sheets of ore that occur

in the clay west of this bed probably represent seams of ore deposited within the marble. Movement of the rocks along slickened joints, which cut the rocks nearly vertically, was so recent that the ore beds and stringers are offset slightly by these faults.

The ore consists chiefly of hard psilomelane but includes also some manganite, pyrolusite, and wad. The two latter minerals in places completely replace sandstone and constitute a friable mass locally known as "black sand" ore, some of which is now being mined from

FIGURE 9. View in north end of pit of Hambright mine. The nearly vertical layer of high grade ore is shown in the central foreground. It curves sharply to the right where the men are working.

the eastern part of the deep workings. Associated with the manganese ore is very pure hematite which also occurs in slabby blocks and preserves impressions of fossils and round pebbles with shiny surfaces, which probably were originally small limestone pebbles in the sandy lime silt and became smooth and rounded by calcareous accretion similar to the formation of oolite.

Several hundred feet south of the main opening, cross trenches 8 or 10 feet deep have been excavated in dark-red sandy clay in

search of the ore zone but were not deep enough at the time of visit to determine its position. It seems reasonable however to expect the ore to continue both north and south of the present workings, although it may be offset by faulting. Cross trenching is therefore the best method of locating it.

WHITE OAK MOUNTAIN MINE.

Deposit in Fort Payne Chert.

The White Oak Mountain mine is in Bradley County on the upper east slope of White Oak Mountain, eight miles northwest of Cleveland, which is on the Chattanooga division of the Southern Railway. The mine is owned and operated by the White Oak Manganese Corporation of Cleveland, Tenn., and Pittsburgh, Pa., of which J. E. Newlands is president. The property covers 998 acres, the title to a large part of which is now in litigation, and the mine has consequently been shut down.

The deposits are widely distributed along the mountain from its crest to near its eastern base, for a length of three miles, and are opened by a number of cuts, pits, and shafts, some to a depth of thirty feet. The ore occurs in part in the Fort Payne chert ledges the structure of which is monoclinal, the rocks dipping 10°-15° SE. At the south end of the property the manganese ore fills joints and fractures in the chert on the crest of the ridge and in part replaces it, forming tabular masses some of which are several inches in thickness. Owing to the paucity of the ore and the large amount of chert or silica which it contains the deposit at this place is probably not of commercial value.

At the north end of the property loose chert and manganese ore in the soil were dug up on the upper slope, and considerable manganese ore, much of it siliceous from the chert it inclosed, was obtained. The largest opening is on a bench about 100 feet below the top of the mountain in the north-central part of the property. It is a trench approximately 80 feet in length by 30 feet in width, and 15 feet in depth. A tunnel also goes into the hill at this place. The ore is in shaly chert dipping gently to the southeast, three layers of which are impregnated with ore. The ore-bearing layers are a foot thick in places, but dip with the mountain slope so that they do not go deep below the surface. About 1,000 tons of ore lie on the dump,

of which about 40 tons are good psilomelane and may average 40 per cent in manganese. The rest of the ore is largely good brown iron ore much of which is manganiferous. A short distance south of the trench on the lower slope of the hill a large shaft has been sunk 75 feet, penetrating 22 feet into black shale below the ore-bearing chert. At the time of visit a four-inch diamond drill hole was also being sunk adjacent to the shaft in order to go deeper into the barren shale, a very wasteful procedure.

Both the iron and manganese ores at this pit can be shipped without washing, but elsewhere the ore will need to be cleaned of clay or silica. The ore will have to be hauled by wagon eight miles to the railroad, about half of the distance over rough hilly roads. The low grade of much of the ore, the scattered occurrence of the better grade of ore, the long distance the ore must be hauled, and the wasteful methods pursued are not encouraging for the development of the property into a profitable mine.

TAYLOR VALLEY MINE.

Deposit Along Fault Plane.

Taylor Valley mine, also called the Reece or Dollars mine, is at Matney, Johnson County, two miles east of Dollars, the nearest station on the Laurel Railroad. It is in the northeastern part of the county, ten miles north-northeast of Mountain City. The property is owned by Mr. Reece of Matney, and the mine is operated by the East Tennessee Mining Company of Mountain City, in which the Southern Manganese Corporation holds an interest. In 1917, 116 tons of ore were shipped to the Southern Manganese Corporation. In the first half of 1918, 142 tons were shipped and about 100 tons were in the bins at the mine. Recent shipments were made to the Tennessee Coal, Iron and Railroad Co. of Birmingham, Ala., and to the Southern Manganese Corporation at Anniston, Ala. The ore is reported to average about 36 per cent in manganese and to contain considerable silica, in some shipments as high as 20 to 25 per cent.

The mine is located on the southwest slope of a spur from Pond or Stone Mountain, on the east side of Owens Branch. It is at an elevation of about 2,900 feet, or about 200 feet above the creek and washer, and is about 100 feet below the crest of the spur. The deposits occur in brecciated sandstone, probably at the base of the

Watauga shale, and in residual clay of the underlying Shady dolomite, and are adjacent to a thrust fault which has brought pre-Cambrian purple schist against the dolomite and sandstone. The pre-Cambrian schist is an altered amygdaloidal lava, locally known as red mountain rock. On the lower slope of the spur northwest of the mine massive blue dolomite of the Shady outcrops with variable low dips to the southward. Northwest of Matney it is overlain by purple shale of the Watauga. Below the mine horizontal dolomite crops about midway up the slope, but the yellow clay and sandstone beds in the main mine pit are probably the basal beds of the Watauga. A thin overburden of three or four feet of clay and soil contains a little ore.

The ore consists chiefly of black impure psilomelane in the form of nodules and aggregates of small pea-sized nodules with concentric structure, some of which are very pure. Much of the psilomelane contains sand grains and larger fragments of silica. Some has a metallic slicksided surface.

The deposits are opened by several pits some of which trend in an easterly direction into the hill and one in a northwesterly direction across the spur. The lowest one, at the head of the flume to the washer, is only a small pit exposing an ore-bearing bed of dark red clay five to eight feet in thickness resting on barren dense yellowish clay or shale. The barren clay is probably residual from Watauga shale, and the overlying ore-bearing clay is probably washed from the ore beds above, in which ore has been redeposited. There is much good float ore on the slope of the hill.

The main pit, about 100 feet higher, is 80 feet long, 20 feet wide, and 15 feet deep. Beneath three feet of brownish chocolate-colored clay overburden horizontally streaked with ore in its lower part, are six feet of yellow clay horizontally seamed with thin streaks of manganese oxide, one foot of dark stiff clay called "buckfat," and three feet of yellow clay containing a considerable amount of good ore. The floor is a soft brecciated sandstone cemented and partly replaced by ore, which appeared to be of good quality. The clay in the southeastern part of the pit is bluish but also contains the same kind of ore. Much of the ore is gritty with sand grains, and nodules of the ore up to four inches in diameter contain much silica in their central parts.

The east pit, which is 50 feet in length by 25 feet in width and about 30 feet in depth, trends northwestward toward the upper end of the main pit. The lower part of the walls was badly caved at the time of visit. The west or foot wall is composed of apparently residual bedded yellow clay and dark manganese-stained clay with a little ore. The east or hanging wall is composed largely of a mixture of purple schist and white sandstone fragments in bluish sand. At its western endge are many slickened surfaces on steep joint planes. The ore occurs in a zone 20 feet wide of dark "buckfat" clay, much jointed and slickened in various directions, and some sand. The ore belt strikes N 20° W and dips 70° to 80° NE. The ore occurs in pockets of wad in the "buckfat" and is said to occur throughout the length of the pit, especially in its eastern half, and to continue to the bottom of the working which was abandoned not for lack of ore but because of the danger of caving of the undercut east wall. Some of the ore and black manganiferous clay is slickened, showing great compression and earth movement. This ore zone undoubtedly occupies a fault zone between the pre-Cambrian schist on the southeast and Watauga shale and Shady dolomite on the northwest. In the middle pit the fault zone has not yet been reached and the ore is distributed in the foot-wall shale. The deposit as a whole seems to be chiefly controlled, therefore, by the circulation of ore-bearing solutions along a fault plane.

A short tram at the mine carries the ore to the head of a flume which descends the hill slope to the two-log washer. Much of the washed ore is of low grade and carries much silica. The fines also contain much fine silica, which is removed by further washings or jigging.

The northward continuation of the ore body has not been determined. On the opposite side of the spur north of the mine and below the capping of overthrust amygdaloid, a test pit 12 feet deep has been sunk in contorted yellow clay, probably Watauga shale, and below in the valley the Shady dolomite crops out. Some psilomelane ore occurs in blotchy yellowish-brown clay in the pit and some large masses of float ore have been found on the surface.

SILVER LAKE MINE.

Deposit in Terraced Stream Gravel.

The Silver Lake mine is at Silver Lake station on the Laurel Railroad, in the north-central part of Johnson County, five miles northeast of Mountain City. It is only a few hundred feet distant from the railroad, and 80 feet above it. The property is owned by Wiley Southerland of Mountain City, who also manages the mine for the Silver Lake Mining Co., a local company. The company began operating in the early part of the present year and from February 1 to the date of visit, May 23, had shipped six tons of ore a day or a total of about 600 tons. Most of the ore was shipped to the Southern Manganese Corporation at Anniston, Ala., and the ore is said to have averaged 45 per cent in manganese. Eighty tons of similar high grade ore and 120 tons of fines averaging 35 per cent manganese were in the bins ready for shipment. About 40 tons of picked iron ore which came from an earlier surficial part of the working were on the dump. At the time of visit a force of 14 men were at work, seven at the mine and seven at the washer.

The mine is located in an open part of the valley of Laurel Creek on top of a small round flat-topped hill 80 feet above Laurel Creek, which flows near its base. The hill is composed of Watauga shale capped by sand and rounded stream gravel six to fifteen feet thick. The shale is in general flat but in minor folds the beds dip 35° SE. The shale is in part unweathered, hard and purple, and in part weathered to soft yellow clay shales. Low ridges on the harder beds trend northeast and the ore seems to lie or be more plentiful in the deeper filling of the troughs between the ridges. The stream gravel consists of red, yellowish, and brownish sand or sandy clay, the upper part of which contains numerous waterworn river pebbles and cobble. Some of the larger quartzite boulders are a foot or more in diameter. These sands and gravels were evidently deposited by Laurel Creek when the valley floor was at this level and the top of the hill was part of the stream channel. The pebbles are mostly clean and free from manganese stain.

Most of the ore occurs in the red sand near the base of the stream deposit, but some occurs in the gravel in the upper part. The ore is chiefly distributed in thin zones one to two inches thick, but rich pockets of nearly solid ore are also found.

The ore is mined from a large open cut about 100 feet across from which deep trenches run irregularly following richer streaks. These are about 10 to 15 feet deep. A shaft 20 feet deep is sunk into barren shale below the bottom of the stream gravels. The ore consists almost wholly of nodules of pure psilomelane some lumps of which are 2½ feet in diameter. Although the ore occurs largely in the lower part of the surficial deposit, there is enough distributed throughout the upper part to warrant treating all the ground removed from the bedrock to the surface in the two-log washer, which is located at the foot of the hill. Some of the clayey layers at the base of the surficial deposits from which a small amount of ore is recovered, may be residual clay from the decomposition of the bedrock.

EAST FORK MINE.[1]

Carbonate Ore in Dolomite.

The East Fork mine is in Sevier County on East Fork of Little Pigeon River, two miles south of the old East Fork postoffice and 13 miles southeast of Sevierville, the present terminus of the Knoxville, Sevierville and Eastern Railroad. It is in a rugged hilly country on the north flank of the Great Smoky Mountains, being located on a low hill south of the stream and about 200 feet above it. The land is known as the Widow Owen's property. It is now owned and operated by the Tennessee Manganese Co. of Knoxville, D. C. Campbell, President.

The mine has not yet begun to produce although a test car load of ore has been shipped. The carbonate ore which composes most of the ore body is apparently a white rhodocrosite containing considerable calcium and magnesium as impurities, or more likely a new mineral containing these three carbonates. It occurs in nearly vertical beds and lenses in slate and dolomite, and is oxidized at the surface to psilomelane and wad. The carbonate ore is reported by the company to contain 37.75 per cent manganese and the oxide ore 48.6 per cent.

The mine is located at the southeast end of a spur from a higher hill to the northwest and is opened by two open cuts, a tunnel, and

[1]This mine was examined by Arthur Keith and G. W. Stose in the spring of 1917 and a joint report was prepared, which may later be published. The description here given is from notes made by them.

FIGURE 10. Workings of the East Fork mine, Sevier County, where carbonate ore is being mined. The second open cut where shaft is now being sunk

a shaft, on opposite sides of the spur. There are also four other small open cuts on other spurs along the lead of the ore which trends S 40° W, covering a length of 4,000 feet. The ore zone follows the contact of slate and dolomite, the slate lying on the southeast, the dolomite on the northwest. The slate is one of the oldest sedimentary rocks in the Appalachian region, called Hiwassee slate, and the dolomite is apparently interbedded in it. The dolomite is about 60 feet thick and in places contains some blue thin-bedded limestone.

The main working, nearest East Fork, consists of an open cut about 60 feet long, ten feet wide, and about 60 feet deep with stepped face. A tunnel 100 feet long follows the ore from the bottom of the cut. (See Fig. 10.) The open cut was designed to take out the oxide ore, which is only five to ten feet thick over the vein, and the work was done mostly before the bedrock vein was discovered to be a manganese ore. The oxide ore is in the form of irregular small masses of psilomelane in wad and light manganiferous clay. Much of the latter is the product of weathering of the inclosing manganiferous dolomite. The tunnel passes into solid carbonate ore at about six feet from the portal. The ore body is lenticular and pinches out at the back end of the tunnel but a bore hole in the southeast wall shows another body of ore in that direction. The open cut above the tunnel also shows the lenticular character of the ore bodies which overlap each other. (See Fig. 10.)

The second working is also an open cut 80 feet long, 8 to 10 feet wide and 40 feet deep stepped in three benches. The carbonate ore is excellently exposed in the two lower benches, showing a body about 4 to 5 feet wide, which pinches out at the face of the lower bench and shows other irregularities in width as it pinches and swells. The upper bench is in oxide ore, chiefly wad with some psilomelane masses.

The shallow propects along the ore lead to the south expose wad and psilomelane mostly in narrow zones, but none of the pits are deep enough to determine the size or shape of the carbonate ore body which they represent. The northernmost of these openings, across the ravine from the second open cut, exposes the solid carbonate ore but its relations were not shown nor its width determined.

The carbonate ore is in part crystalline and in part compact and banded. The crystalline ore seems to have been deposited first, prob-

ably by direct replacement of calcareous rock, either the dolomite or calcareous slate. Manganese minerals which were probably originally disseminated in the dolomite or slate were dissolved by the deeper circulating waters and the manganese was redeposited as a mixed carbonate of calcium, magnesium, and manganese in the rock adjacent to the solution channels. The ore solutions apparently circulated along joints and fissures which follow the contact of the dolomite and slate where there may also have been some faulting. The rhombs of the crystalline mineral show marked zonal structure, the clearer outer portion probably carrying less manganese. The coarsely crystalline character of this ore indicates that it was probably deposited some distance from the surface, below the zone of surface oxidation. The banded amorphous or cryptocrystalline carbonate, in which thin layers of black oxide of manganese are interlaminated, seems to fill open spaces in the crystalline mass and is probably a later enrichment in the zone of oxidation near the surface.

An analysis of the carbonate ore made for the company is reported as follows:

Mn	37.75
SiO_2	7.
CaO	5.26
MgO	2.30

Analyses of two small fragments of ore, selected to represent the two types of ore, crystalline and banded, were made in the laboratory of the U. S. Geological Survey[1] as follows:

	Crystalline Carbonate Ore.	Banded Carbonate Ore.
Mn	9.29	26.33
CaO	22.10	11.58
MgO	11.63	3.
SiO_2	9.53	15.54

The ore body and wall rock contain considerable pyrite much of which, especially that in the wall rock, is rather coarsely crystalline (pyritohedrons), whereas minute crystal aggregates are scattered through the banded ore. Quartz is also common in small stringers, in some of which bright anthracitic carbon is inclosed. A few small calcite veinlets cut the ore.

Since the mine was visited an experienced engineer has been engaged by the company who is sinking a working shaft at the second

[1]Analyst, George Steiger.

opening, from which drifts will be run northeast into the hill and in the opposite direction below the ravine surface. A site has been purchased at Knoxville where it is contemplated to build an electric furnace to treat not only the ores of this mine but also the oxide ores from other mines in this part of the State. The great handicap of a haul of 13 miles from the mine to the railroad, one-third of which is over roads at present almost impassable, is offset by the short railroad haul to Knoxville if the furnace is established there and by the fact that the ore is partly self fluxing.

Although the analyses of samples of rock selected to represent types of mineral occurrence show but 9 to 26 per cent manganese, it is reasonable to believe that the run of mine will show a larger per cent of manganese possibly more nearly that obtained by the company from its sample, 37 per cent. Should the ore body prove to continue to a depth of 50 or more feet below the tunnel level at the north opening with an average thickness of 4 to 5 feet, as it appears to have in the surface exposures, the ore body will be of considerable size and tonnage, and should it be found to be of workable size throughout the length of the property toward the south, 4,000 feet, the tonnage will be many times greater.

List of Manganese Mines and Prospects in East Tennessee.

(Geographically by counties, beginning at the northeast corner of the State.)

County.	Mines and Prospects.	Location.	Owner.	Operator.	Distance to Railroad and Shipping Point.	Type of Deposit.
Johnson	Taylor Valley or Reece Mine	Matney	—— Reece	East Tennessee Mining Co.	2 miles to Dollars on Laurel R. R.	Fault plane
Johnson	Silver Lake mine	Silver Lake	Wiley Southerland	Silver Lake Mining Co.	On Laurel Railroad	Terraced stream gravel
Johnson	Wills mine	1 mile east of Wills	Oscar Wills	Laurel Mining Co.	1½ miles to Wills on Laurel R. R.	Shady dolomite
Johnson	King prospect	3 miles northeast of Mountain City	Nelson King	(Undeveloped)	3 miles to Mountain City on Laurel R. R.	Shady dolomite
Johnson	Shouns prospect	2 miles south of Mountain City	Virginia Iron, Coal & Coke Co.	(Undeveloped)	1 mile to Shouns on Southern R. R.	Watauga shale
Johnson	Davis mine	½ mile northwest of Crandull	W. P. Parker and E. N. Martin.	George E. Davis and Southern Manganese Corp.	½ mile to Crandull on Beaver Dam R. R.	Shady dolomite
Johnson	Davis prospect (reported)[1]	2 miles (?) southeast of Crandull		George E. Davis	2 miles to Crandull on Beaver Dam R. R.	Shady dolomite
Johnson	King prospect	1 mile northwest of Shady	—— King		¼ mile to Beaver Dam R. R.	Shady dolomite
Johnson	Maxwell mine	1 mile southwest of Shady		Maxwell Manganese Mining Co.	½ mile to Beaver Dam R. R.	Shady dolomite
Johnson	Wright prospect	1½ miles southwest of Shady	—— Wright	Maxwell Manganese Mining Co.	½ mile to end of Beaver Dam R. R.	Shady dolomite
Johnson	Osborn prospect	2 miles southwest of Shady.	Alec Osborn	Alec Osborn	1 mile to end of Beaver Dam R. R.	Shady dolomite

[1]Prospects marked "reported" were obtained by correspondence or through other persons and not by personal visit.

List of Manganese Mines and Prospects in East Tennessee—Continued.

County.	Mines and Prospects.	Location.	Owner.	Operator.	Distance to Railroad and Shipping Point.	Type of Deposit.
Johnson	Hopper prospect	2 miles south-southwest of Shady	—— Hopper	George E. Davis	1 mile to end of Beaver Dam R. R.	Shady dolomite
Johnson	Doe Valley or Fritz mine...	7 miles southwest of Mountain city	—— Fritz	East Tennessee Mining Co.	7 miles to Mouth of Doe on Virginia & Swn. R. R. ..	Watague shale
Johnson	Proffit prospect (reported)..	5 miles northeast of Butler.	Stacy Proffit	(Undeveloped)	2 miles to Mouth of Doe on Va. & Swn. R. R.	Shady dolomite
Johnson	Wilson Hill or Superior mine	1 mile south of Neva	Superior Manganese Corp.	Superior Manganese Corporation	1 mile to Neva on Virginia & Southwestern R. R.	Shady dolomite (faulted?)
Johnson	Wagner prospect	5 miles northeast of Butler at head Little Dry Creek.	D. A. Wagner...	A. H. and J. J. McQueen...	5 miles to Butler on Virginia & Southwestern R. R. ...	Shady dolomite
Johnson	Dry Run mine	3½ miles northeast of Butler	.....	A. H. McQueen	3½ miles to Butler on Virginia & Swn. R. R.	Shady dolomite
Johnson	Watauga River mine	2 miles southeast of Butler.	.....	J. L. McQueen	2 miles to Butler on Virginia & Southwestern R. R. ...	Watauga shale
Johnson	Cable prospect	2 miles southeast of Butler.	—— Cable	—— Reece	2 miles to Butler on Virginia & Southwestern R. R. ...	Watauga shale
Johnson	Goss mine	2½ miles south of Casper..	.....	Dr. Goss	5 miles to Butler on Virginia & Southwestern R. R. ...	Shady dolomite or Watauga shale?
Johnson	Moody prospect	2 miles south of Casper....	W. R. Moody...	C. H. White	5 miles to Butler on Virginia & Southwestern R. R. ...	Shady dolomite or Watauga shale?
Carter	Blevins mine	1½ miles northwest of Colesville	Mrs. Isaac Blevins	Captain Robinson	1½ miles to Colesville on branch of Va. & Swn. R. R.	Shady dolomite

Carter	Hatcher prospect	1 mile east of Sadie	—— Hatcher?	H. E. Graves	1 mile to Sadie on branch of Va. & Swn. R. R.	Shady dolomite
Carter	Grindstaff prospect	1 mile east of Sadie	G. L. Grindstaff.	(Undeveloped)	1 mile east of Sadie on branch of Va. & Swn. R. R.	Shady dolomite
Carter	Keesburg prospect	1 mile east of Keesburg	Southern Minerals Corporation	Southern Minerals Corporation	1 mile to Keesburg on Va. & Swn. R. R.	Shady dolomite? Watauga shale
Carter	Cobb Creek prospect (reported)	2 miles northwest of Butler.		A. H. McQueen	3 miles to Butler on Va. & Southwestern R. R.	Shady dolomite
Carter	Blue Springs mine	4 miles east of Hunter	Carrigan heirs	Walker and McKenna	4 miles to Hunter on Va. & Southwestern R. R.	Shady dolomite
Carter	Elk mine	2½ miles south of Butler	—— Hately	McQueen Manganese Co.	2½ miles to Butler on Va. & Southwestern R. R.	Watauga shale
Carter	Dubault prospect	2 miles southwest of Butler	—— Dubault	—— Reece	2 miles to Butler on Va. & Southwestern R. R.	Watauga shale
Carter	Younce prospect	2 miles southwest of Butler	S. S. Younce	—— Reece	2 miles to Butler on Va. & Southwestern R. R.	Watauga shale
Carter	Cardens Bluff mine	½ mile southwest of Cardens Bluff		A. D. Reynolds and L. L. McQueen	½ mile to Cardens Bluff on Va. & Southwestern R. R.	Shady dolomite
Carter	Cedar Hill mine	1 mile south of Hampton	Stiles heirs	Maxwell Manganese Mining Co.	1 mile to Hampton on East Tenn. & W. N. C. R. R.	Shady dolomite
Carter	Valley Forge mine	1 mile southeast of Valley Forge		H. W. and A. D. Reynolds.	1 mile to Valley Forge on E. T. & W. N. C. R. R.	Shady dolomite
Carter	Jenkins prospect	2 miles southwest of Valley Forge	Abe Jenkins heirs	J. N. Koch, Davis, and Smith	2 miles to Valley Forge on E. T. & W. N. C. R. R.	Shady dolomite

List of Manganese Mines and Prospects in East Tennessee—Continued.

County.	Mines and Prospects.	Location.	Owner.	Operator.	Distance to Railroad and Shipping Point.	Type of Deposit.
Carter	Hyder prospect	2½ miles southwest of Valley Forge	Hyder heirs	J. N. Koch, Davis, and Smith	3 miles to Valley Forge on E. T. & W. N. C. R. R.	Shady dolomite
Carter	Winter mine	6 miles southeast of Johnson City	Taylor heirs	Maxwell Manganese Mining Co. (inactive)	4 miles to Watauga Point on E. T. & W. N. C. R. R.	Shady dolomite
Carter	Patton mine	6 miles southeast of Johnson City	Taylor heirs	Maxwell Manganese Mining Co. (inactive)	4 miles to Watauga Point on E. T. & W. N. C. R. R.	Shady dolomite
Carter	Treadway prospect	6 miles southeast of Johnson City	Geo. Treadway	W. H. Kemler	3 miles to Carolina, Clinchfield & Ohio R. R.	Shady dolomite
Carter	Hodge prospect	6 miles southeast of Johnson City	Frances Hodge	W. H. Kemler	3 miles to railroad	Shady dolomite
Carter	T. J. Brummett mine	5 miles northeast of Unicoi.	T. J. Brummett	Southern Manganese Corporation	5 miles to Unicoi on railroad	Shady dolomite
Unicoi	Susan Brummett mine	4 miles northeast of Unicoi.	Mrs. Susan Brummett	Southern Manganese Corporation	4 miles to Unicoi on railroad	Shady dolomite
Unicoi	Britt mine	3 miles northeast of Unicoi.	J. L. Britt	Southern Manganese Corporation	3 miles to Unicoi on railroad	Shady dolomite
Unicoi	Embreeville prospect	2 miles southwest of Embreeville	Embree Iron Co.	Embree Iron Co.	2 miles to Embree on mine branch, Southern R. R.	Shady dolomite
Greene	Haysville prospect	12 miles south of Greeneville	Unaka Development Corp.	Unaka Development Corporation	12 miles to Greeneville on Bristol-Chat. line, So. R. R.	Shady dolomite (faulted)

Greene	Sylvia prospect	14 miles south of Greeneville		Leroy and J. C. Park	12 miles to Greeneville on Bristol-Chat. line, So. R. R.	Shady dolomite
Greene	Lamb prospect	15 miles south of Greeneville	Scott Lamb	(Inactive)	15 miles to Greeneville on Bristol-Chat. line, So. R. R.	Shady dolomite
Cocke	Wood mine	5 miles northeast of Del Rio	Nick Wood	(Inactive)	5 miles to Del Rio on Morristown-Asheville line, Southern R. R.	Shady dolomite
Cocke	Huff prospect	4 miles northwest of Del Rio	Aleck Huff	(Inactive)	4 miles to Del Rio on Morristown-Asheville line, Southern R. R.	Shady dolomite
Cocke	Long Creek prospect	3 miles northwest of Del Rio	Aleck Huff	(Inactive)	3 miles to Del Rio on Morristown-Asheville line, Southern R. R.	Shady dolomite
Cocke	Adams mine	3 miles west-northwest of Del Rio	Jno. N. Adams	(Inactive)	On Morristown-Asheville line, Southern R. R.	Shady dolomite
Cocke	Blanchard mine	3 miles west-northwest of Del Rio	William Blanchard	Barium Lithophane Co. (Inactive)	1 mile to Morristown-Asheville line, So. R. R.	Shady dolomite
Cocke	Waddell mine	3½ milest west of Del Rio	John B. Waddell	(Inactive)	1½ miles to West Meyers on Morristown-Asheville line, Southern R. R.	Nebo quartzite
Cocke	Raines prospect (reported)	3¾ miles west of Newport	Barney Hurley	(Inactive)	3¾ miles to Newport on Morristown-Asheville line, Southern R. R.	Shady dolomite
Cocke	Jones and McMahon prospect	4¼ miles west of Newport	Jones & McMahor	(Inactive)	4¼ miles to Newport on Morristown-Asheville line, Southern R. R.	Shady dolomite
Cocke	Newport mine	4¾ miles west of Newport	Sant estate	Manganese Products Co.	4¾ miles to Newport on Morristown-Asheville line, Southern R. R.	Shady dolomite
Hamblen	Lotspeich ? prospect (reported)	3 miles southeast of Morristown?		J. N. Lotspeich?	3 miles from Southern R. R.	Knox dolomite?

List of Manganese Mines and Prospects in East Tennessee—Continued.

County.	Mines and Prospects.	Location.	Owner.	Operator.	Distance to Railroad and Shipping Point.	Type of Deposit.
Grainger	Rutledge mine	2 miles southeast of Rutledge	J. H. Lowe	J. S. Swann	3 miles to Rutledge on Knoxville-Bristol line, So. R. R.	Knox dolomite (base)
Grainger	Harmon prospect	2½ miles southeast of Rutledge	Joe Harmon	(Undeveloped)	2½ miles to Rutledge on Knoxville-Bristol line, So. R. R.	Knox dolomite (base)
Grainger	Young prospect (reported)..	6 miles south of Rutledge..	B. F. Young	(Undeveloped)	6 miles to Rutledge on Knoxville-Bristol line, So. R. R.	Knox dolomite
Grainger	Wallen prospect	Puncheon Camp, 4 miles northeast of Washburn...	Wm. Wallen	(Undeveloped)	4 miles to Washburn on Knoxville-Morristown line, Southern R. R.	Knox dolomite (top)
Grainger	Frye prospect	1½ miles northwest of Washburn	Chas. Frye	(Undeveloped)	1½ miles to Washburn on Knoxville-Morristown line, Southern R. R.	Knox dolomite
Jefferson	Curren prospect (reported).	Near Jefferson City	George Currens ..	(Undeveloped)	Near Jefferson City on Southern R. R.	Not known
Sevier	East Fork mine	12 miles southeast of Sevierville	Tennessee Manganese Company.	Tennessee Manganese Company	12 miles to Sevierville on Knoxville, Sevierville & Eastern R. R.	Carbonate ore in older dolomite
Blount	Townsend prospect (reported)	13 miles southeast of Maryville	.....	(Undeveloped)	1 mile to Townsend on K. & A. branch of So. R. R....	Fault plane?

Blount	Chilhowee prospect (reported)	12 miles south of Maryville.		H. E. Colton (deceased)	2 miles ? to Chilhowee on T. and C. S. branch of So. R. R.	Fault plane?
Blount	Miller prospect (reported)	9 miles south of Maryville.	Rufus Miller	(Undeveloped)	6 miles to Chilhowee on T. & C. S. branch of So. R. R.	Fault plane?
Blount	Louisville mine	4 miles southwest of Louisville	J. B. Cox	M. M. Whittle	1 mile from Louisville and Nashville R. R.	Holston marble (base)
Blount	—— prospect (reported)	2 miles southwest of Louisville			1 mile from Louisville & Nashville R. R.	Holston marble
Knox	Haworth prospect (reported)	2 miles northwest of Powell	W. L. Haworth	(Undeveloped)	2 miles to Powell on Knoxville-Clinton branch of Southern R. R.	Knox dolomite
Anderson	Howell prospect (reported)	5 miles north of Clinton	D. A. Howell?	D. A. Howell and S. M. Bright	5 miles to Clinton on Louisville and Nashville R. R.	Watauga shale?
Loudon	Galbraith mine	8 miles southeast of Loudon	Charles Galbraith	Southern Manganese Corporation	8 miles to Lenoir on Southern R. R.	Holston marble
Loudon	Cates prospect (chiefly iron)	2 miles south of Loudon	J. K. Cates	LaFollette Mining Co.	2 miles to Loudon on Southern R. R.	Fault?
Monroe	Mills prospect	8 miles east-northeast of Sweetwater	J. C. Mills	Southern Manganese Corporation	8 miles to Philadelphia on Southern R. R.	Holston marble
Monroe	McGuire mine	4 miles north-northeast of Sweetwater	Frank McGuire	Southern Manganese Corporation	½ mile to Southern R. R.	Holston marble
Monroe	Vita mine (chiefly iron)	3 miles north-northeast of Sweetwater		Fitzgerald and Smith	½ mile to Vita switch on Southern R. R.	Holston marble
Monroe	Heiskell mine	1½ miles northeast of Sweetwater	Harry Heiskell	H. L. Smith	1½ miles to Sweetwater on Southern R. R.	Holston marble
Monroe	McDonald prospect	3 miles southeast of Sweetwater	—— McDonald	Southern Manganese Corporation	5 miles to Sweetwater on Southern R. R.	Knox dolomite

List of Manganese Mines and Prospects in East Tennessee—Continued.

County.	Mines and Prospects.	Location.	Owner.	Operator.	Distance to Railroad and Shipping Point.	Type of Deposit.
Monroe	Kembrough prospect (reported)	4 miles northeast of Madisonville	—— Kembrough.	(Undeveloped)	2 miles to Norfolk & Western R. R.	Knox dolomite?
Monroe	Ervin prospect	5 miles northwest of Tellico Plains	—— Ervin	—— Ervin	2 miles to Mt. Vernon on Louisville & Nashville R.R.	Holston marble
Monroe	Groundhog Mountain prospect	3 miles west of Tellico Plains	J. H. Curd	Southern Manganese Corporation	4 miles to Tellico Plains on Louisville & Nashville R.R.	Shady dolomite (faulted)?
Monroe	Dickey prospect (reported).	3 miles northwest of Sweetwater	—— Dickey	(Undeveloped)	3 miles to Sweetwater on Southern R. R.	Knox dolomite?
McMinn	Hansard prospect	3 miles southwest of Sweetwater	J. B. Hansard	(Undeveloped)	2 miles to Southern Railroad	Knox dolomite
McMinn	Webb prospect (reported).	10 miles northwest of Calhoun	—— Webb	(Undeveloped)	12 miles to Calhoun on Southern R. R.	Knox dolomite
McMinn	Patton prospect (reported).	10 miles northwest of Calhoun	—— Patton	(Undeveloped)	12 miles to Calhoun on Southern R. R.	Knox dolomite
McMinn	Red Hills prospect (reported)	3 miles east of Calhoun		(Undeveloped)	4 miles to Calhoun on Southern Railroad	Holston marble
Bradley	Underwood mine	4 miles southeast of Charleston		W. B. Underwood	4 miles to Charleston on Southern Railroad	Holston marble

Bradley	White Oak Mountain mine.	8 miles northwest of Cleveland	White Oak Manganese Corp. ..	White Oak Manganese Corporation	8 miles to Cleveland on Southern R. R.	Fort Payne chert
Bradley	Brown prospect (reported)..	8 miles west of Cleveland..	Jake M. Brown..	(Undeveloped)	6 miles to McDonald on Southern Railroad	Fort Payne chert
Bradley	Hambright mine	8 miles south of Cleveland.	—— Hambright .	Fitzgerald & Lanskey	2½ miles to Marble Switch on Southern Railroad ...	Holston marble
Bradley	Jones prospect	9 miles south of Cleveland.	M. V. Jones	M. V. Jones	2 miles to Marble Switch on Southern R. R.	Holston marble
Bradley	Sloan prospect	10 miles south of Cleveland.	W. B. Sloan	W. B. Sloan	3 miles to Marble Switch on Southern R. R.	Holston marble
Bradley	D. A. M. mine	10½ miles south of Cleveland	Davis, Artz & McCrossin	Davis, Artz & McCrossin..	2 miles to Weatherly Switch on Southern Railroad ..	Holston marble
Bradley	Lord mine	11 miles south of Cleveland	—— Boyd	C. H. Lord Corporation....	1¼ miles to Weatherly Switch on Southern R. R.	Holston marble
Bradley	Hannah prospect	13 miles south of Cleveland	Mrs. Hannah ...	C. H. Lord Corporation....	2½ miles to Weatherly Switch on Southern R. R.	Holston marble

War Work

The war policy of the State Geological Survey is to give its entire energy and resources to whatever degree necessary to war work and the winning of the war. We hear different slogans wherever we turn, "Saving will win the war;" "Food will win the war;" "Ships will win the war," and many others, all good and necessary, but the one great idea back of it all is that "Home production will win the war." Believing this, the Survey, as one of the home divisions of the army overseas, is devoting its whole organization to "carrying on."

To the State Geological Survey and to the new State Geologist just entering on his duties, there comes the great and vitally important work of locating all those necessities except food, so that once located, they may be developed and their production speeded up to the highest notch of efficiency.

It is hard for the public to realize the grave condition in which our country will find itself, unless sufficient war minerals are produced at home and produced quickly. How closely is victory tied to mining production can be recognized by all when they know that several hundred thousand dollars worth of shells and ammunition were often used in twenty-four hours on any one of the quiet sectors that were occupied by the United States troops when they first went on the battle front. This naturally represents a large tonnage of special ammunition metal produced by mining the different ores necessary for the mixture, smelting them and bring them together in the final metal alloy that is used in making the different guns and shells now used. In addition to the ores, that are mined and are used as the basis for these supplies, there is an enormous amount of coal necessary in each mining, smelting and manufacturing process through which the ore goes. It has been stated that for every ton of three-inch shells produced, it is necessary to mine and use four tons of coal.

In the past we have imported almost our entire supply of a number of necessary war minerals, most notable of which are manganese and pyrite. Without these minerals and their products the munition industry would come to a standstill.

Tennessee has the greatest number of minerals in workable quantity of any state in the Union, and we are especially fortunate in hav-

ing deposits of both manganese, pyrite and other war minerals, both in known areas, now being worked and in undeveloped areas where new deposits may be found. Our manganese before the war came from Brazil, Russia and India, and our pyrite mostly from Spain. We have both the minerals in the United States but due to the low price at which these foreign ores were sold in our country, domestic production was impossible. Now everything is changed, these ores are cut off, due to lack of ships and internal conditions abroad.

In 1914, Germany, knowing how essential manganese was to present day warfare, had acquired a stock that she estimated would last her for two years. In the fall of 1917, it has been stated, that she was in dire need of a new supply of this ore. By utilizing scrap and all local supplies, that she could lay hands on, she was able to make out until 1917. When Russia collapsed, Germany obtained control of one of the world's largest manganese areas, by taking over Ukraine. Many people think that it was this ore in Ukraine, more than food, that made Germany occupy this region under a so-called peace agreement.

The State Geological Survey is now working continually to locate new deposits of manganese in Tennessee and to get them developed. In the past Tennessee was known as a place where manganese occurred more in the form of a specimen than anything else, while now it is recognized as one of the leading producing states. There are now 11 manganese washer plants in operation, and in addition, there are a number of dry mines now being worked that are producing considerable tonnage. In all of this work the State Geological Survey has received the full co-operation of both the U. S. Geological Survey and the U. S. Bureau of Mines and the progressive patriotic citizens of our country.

It has been said that the degree of civilization of a country can be determined by the amount of sulphuric acid that it uses. This acid is made from pyrite or brimstone and is much more an essential necessity of present day war than it is of civilization, for most of our explosives can only be made by the use of this acid. Our pre-war requirements for acid were insignificant when compared to our present estimated needs and this estimate increases monthly.

Ducktown, Tennessee, for years had the distinction of having the largest sulphuric acid plant in the world, and one that utilized the fumes from the copper smelters at that place. Now the plant at Duck-

town is small compared to some mammoth plants constructed for war use, but Tennessee still has the distinction of having within her borders one of the largest of these mammoth plants. This is the plant at the government powder plant in Hadley's Bend, near Nashville.

When the government, at the beginning of the war, called for increased production of pyrite in this county, the operating mines responded and shipped a greater tonnage. The point was soon reached when all these mines were producing to their limit. Then it was necessary to find new supplies. To open new mines, even if they can be found, takes time. The question was how can the supply of pyrite be increased. So all the occurrences of pyrite were tabulated, and it was shown that the greatest possibility lay in utilizing the waste pyrite from the coal mines of our country. This was a by-product that most of the mines had considered a nuisance and thrown away. There was one mine in Tennessee that was saving its pyrite and shipping it to one of the chemical companies. Now every mine that has been visited has agreed to save pyrite and ship it to some acid producer. The coal operators have been put in direct touch with the acid producers and more pyrite is being saved for war purposes.

Another war activity of the State Geological Survey is on the ball clay deposits, suitable for crucible, glass pots and electric insulators. Mines are operating in West Tennessee on clays suitable for making these articles and new deposits are being prospected daily. Our Tennessee clays are replacing imported clays and giving satisfactory results to the clay manufacturers.

Each section of our state contains minerals necessary for winning the war, and each section is developing these minerals and doing its utmost for the needs of our country.

The Glenmary Oil Field

BY L. C. GLENN.

During the summer of 1916 a well, known as Pemberton No. 1, was drilled at Glenmary, Tennessee, and obtained oil from the Newman, or St. Louis, limestone, at a depth of 1,232 feet. A second well, known as the Todd No. 1, was at once started, but encountered numerous delays. While this latter well was still drilling the writer published an account of the oil find in the "Resources of Tennessee," Volume VII, Number 1, and this was followed in the next, or April 1917, issue of the "Resources of Tennessee," by an article by Dr. Purdue, describing the bringing in of the Todd No. 1 as a successful oil well. The completion of these two wells started an active drilling campaign about Glenmary that has developed some interesting features. It is the purpose of the present article to give a brief account of the developments since the drilling of the second, or Todd No. 1 well, and to point out the conclusions of a practical nature that may be drawn from a study of the wells so far drilled.

The Todd No. 2, drilled two hundred yards south of the Todd No. 1, obtained a little oil but soon went dry. The Todd No. 3 was drilled two hundred fifty yards northwest of the No. 1 and obtained gas and oil. Todd Nos. 1 and 3 are together now pumping between six and seven barrels of oil per day. This oil is delivered into a tank at Rugby Road and shipped by railway to Somerset, Kentucky, where it is delivered to the pipe line. An analysis of the oil from these two wells will be given later in this article.

The Williams No. 1 was drilled about three-fourths of a mile southwest of Rugby Road and obtained about two and one-fourth million feet of gas. The Rugby Land Company, No. 1, was drilled 900 feet west-northwest of the Williams No. 1 and has obtained about one and one-half million feet of gas that is so wet that the well is blown occasionally to clear the pipes of accumulated oil. Several hundred yards west of this last well, the Stonecipher No. 1 was drilled in the early part of May and when connected to a tank about a week later, is said to have pumped something like a hundred barrels the first day. It has not been possible to learn what its subsequent per-

formance has been. It is west of, and structurally somewhat higher than, the Williams No. 1 or the Rugby Land Company No. 1, both of which obtain gas. Two other locations have been made near the Stonecipher No. 1 and will be drilled at once.

On the bank of Black Wolf Creek, 300 yards east of Pemberton No. 1, the Hagemeyer No. 1 starting at an elevation of 1,250 feet, found only a slight show of oil and gas. The Chattanooga Black Shale was found from 1,630 to 1,750 in depth and the well ended at 1,805 feet in a gray limestone.

About 400 feet southwest of the Pemberton No. 1, the G. Pemberton No. 2 has recently been drilled and will make a small well. Another location has been made 400 feet north of it and a mile west of it, near the old Strubbe well, still another well has been located.

Some 250 to 300 yards northwest of the Todd No. 3, the Jim McCart Nos. 1 and 2 have been drilled for the Fisher Oil Company. The more northerly of these, or No. 1, flowed at first and four 250 barrel tanks were filled. It had considerable gas and produced until the No. 2 tapped the gas fissures when it ceased flowing. It later came back again and then failed once more. The No. 2 showed considerable gas and sprayed a little oil for some time, but has since given out and been plugged. The pumping of these two wells affected each other and also affected the Todd No. 3, although the latter is still producing oil, while the others are not.

On top of the hill 500 yards southwest of the station at Glenmary and 175 feet above station level, which is given as 1,275 feet above sea level, the Ohio Fuel Company have recently gotten a gas well at a depth of 1,445 feet. The yield of gas was not ascertained. The well has been plugged.

A quarter of a mile south of the station the Anna Pemberton No. 1 starting at about 1,265 feet elevation, got oil at 1,347 to 1,362 feet depth in the Newman, or St. Louis, limestone and a few weeks after completion gauged about 340 barrels per day. The oil was accompanied by so much gas that after flowage had been started by pumping, it was maintained by the gas pressure. Oil was shipped by tank cars for some time, the total production being unknown, but probably amounting to several thousand barrels. Meanwhile, the Anna Pemberton No. 2 was drilled on the same level 400 feet south of the first well and obtained some oil and gas, at 1,390 feet. The

difference in stratigraphic level between the rocks in the two wells is almost nothing, so that this oil came from slightly lower in the limestone than that in No. 1. When No. 1 was pumped, gas was soon taken from No. 2, showing that the fissures were connected. This connection was not free enough, though, to permit a free movement of oil between the two wells. Anna Pemberton No. 3, drilled 400 feet south of the last well, found only a show of oil at the general horizon at which it had been obtained in the two preceding wells. It was drilled deeper and obtained a further show of oil in a sand immediately above the Chattanooga Black Shale. This sand reported to be 26 feet thick, corresponds to the Beaver sand. When tested after standing 24 hours, 7 barrels were bailed from this well. The Anna Pemberton No. 2 was deepened to this lower sand and the two wells were pumped for sometime and a number of cars of oil were shipped. Later they both went dry and have since been plugged. In the Anna Pemberton No. 3, the Chattanooga Black Shale was found from 1,730 to 1,805 feet depth. The well ended in 20 feet of red lime—possibly the Clinton—at a depth of 1,805 to 1,825 feet, and ended at 2,050 feet in gray lime.

The oil from the Anna Pemberton No. 3 did not appear materially different from that from the St. Louis limestone. It seemed to the writer that it might have run down the hole from the St. Louis limestone, where a showing was reported, instead of having come from the Beaver sand. If the St. Louis showing had been cased off or the Beaver shut off by a packing, it could have been definitely determined just where the oil came from. The writer secured a sample of the oil and one from the tank into which the Todd Nos. 1 and 3 were pumped. These were submitted to the Survey Chemist, Dr. Hinds, for analysis, the results of which are appended to this article. These results agree so closely that the writer is inclined to think the two are the same oil.

Analysis of Petroleum, Todd Wells Nos. 1 and 3. Producers' Oil Company, Elgin, Tennessee.

Results:

Base—Paraffin.
Color—Dark brown.
Specific Gravity—15.5 degrees C. or 60 degrees F.
Picnometer—0.842.
Paume—36.2 degrees.

Water—Trace. Begins to boil at 45 degrees C.
Sulphur—0.17 per cent.

Distilled from Engler Flask, Moderate Separation.

	Per Cent by Vol.	Per Cent by Weight	Specific Gravity	Baume
Naptha—to 150 degrees C.	21.4	18.82	0.279	62.0 deg.
Burning oil 150 to 300 degrees	32.6	31.94	0.815	41.6 deg.
Residue	46.0	49.24	1.07	

Analysis of Petroleum, Anna Pemberton Well No. 3, Glenmary, Tenn.

Results:
Base—Paraffin.
Color—Dark brown.
Water—Trace.
Specific Gravity—15.5 degrees C. or 60 degrees F.
Picnometer—0.837.
Baume—37.9 degrees.
Sulphur—0.14 per cent.

Distilled from Engler Flask Without Beads, Moderate Separation.

	Per Cent by Vol.	Per Cent by Weight	Specific Gravity	Baume
Naptha—up to 150 degrees C.	19.5	16.36	0.721	63.7 deg.
Burning oil—150 to 300 degrees C.	33.5	32.21	0.805	44.1 deg.
Residuum—above 300 degrees C.	47.0	51.43	0.913	

Samples of the Beaver sand showed a finely chopped mixture of fine grained sandstone and dolomite. The dolomite was probably from a somewhat higher level.

Analysis of Beaver Sand from Anna Pemberton No. 3 Well at Glenmary, Tenn.

Residual insoluble in acids (silica mainly)	69.22
Fe_2O_3, Al_2O_3 and dissolved SiO_2	1.92
$CaCO_3$	16.75
$MgCO_3$	9.65
Undetermined	2.48
	100.00

The Anna Pemberton No. 1, after producing so freely for some time, suddenly went dry and since that time it has been possible to obtain only a barrel or two after letting the well stand for a week or

more. When being pumped it would take the gas from the No. 2 well, in a couple of hours, and it is reported that No. 2 and No. 3 affected each other in a similar manner when either was pumping. The Anna Pemberton No. 3 is the deepest well at Glenmary. Its log is as follows:

Log of Anna Pemberton Well No. 3. Elevation About 1,270 Feet.

	Thickness:	From:	To:
Soil	5	0	5
Slate	35	5	40
Lime (really sandstone)	20	40	60
Slate	40	60	100
Lime (really sandstone)	20	100	120
Slate	245	120	365
Sand	10	365	375
Slate	130	375	565
Salt sand (base of Lee)	303	505	808
Slate	27	808	835
Lime	15	835	850
Redrock	10	850	860
Slate and shells (base of Pennington)	190	860	1,050
Lime (top of St. Louis)	20	1,050	1,070
Slate	36	1,070	1,106
Lime	34	1,106	1,140
Pencil cave (shale)	8	1,140	1,148
Lime	42	1,148	1,190
Slate	16	1,190	1,206
Lime—gas at 1,390	293	1,206	1,499
Sand, showing of oil	10	1,499	1,509
Lime	195	1,509	1,704
Sand, showing of oil (Beaver sand)	26	1,704	1,730
Chattanooga Black Shale	75	1,730	1,805
Red Lime—Clinton	20	1,805	1,825
Gray Lime (probably Ordovician)	225	1,825	2,050

Casing 10 inches, 28 feet; 8 inches, 808 feet; 6 5-8 inches, 1,206 feet. Completed February 21, 1918. J. C. Amsler, Contractor; Charles E. and W. L. Russell, owners.

About 175 feet west of the Anna Pemberton No. 2, the Joel McCart was drilled just west of the railroad, to a depth of 1,450 feet, but got neither oil nor gas, and off-setting well drilled about 60 feet from it, to a depth of 1,526 feet, was also entirely dry. These wells started only 10 feet or less above the level of the Anna Pem-

berton wells. They show that the limestone just where they were drilled was without oil bearing fissures. One location north of these, another rig was erected but no drilling has been done.

Near the old coke-ovens, three-fourths of a mile east of the Anna Pemberton wells, a well is now being drilled and has reached a depth of over 1,400 feet. It has so far obtained a showing of gas only.

OTHER WELLS IN THE REGION.

At Helenwood a well designed for a deep test is now drilling below 1,700 feet. The well mouth is at an elevation of about 1,365 feet and is ten feet below the top of the Lee formation. The base of the Lee formation was reached at 905 feet and the top of the St. Louis, or Newman limestone at 1,160 feet. So far only slight shows of oil and gas have been obtained. It is proposed to drill this well 3,000 feet or more, if necessary. If so, it will become the deepest test in the entire region. The deepest well, so far, known to the writer in that general region is the State's deepest test at Petros, which is 2,940 feet deep. This was drilled in 1898. The log is of considerable interest, has never been published, and is inserted here because of the light it throws on the deeper lying rocks of the region.

Log of Well No. 2, Drilled in Prison Yard at Petros. Elevation of Well Mouth 1,468 Feet.

	Thickness	Depth
Soil	10′	0-10′
Shale	15′	10′-25′
Blue Sandstone	59′	25′-84′
Blue Slate	15′	84-99′
Gray Sandstone	26′	99′-125′
Slate	115′	125′-240′
Sandstone	17′	240′-257′
Coal	3′ 6″	257′-260′ 6″
Sandstone	44′ 6″	260′ 6″-305′
Shale	145′	305′-450′
Coal	Thickness not given	
Shale	155′	450′-605′
Sandstone (top of Lee conglomerate)	80′	605′-685′
Shale	70′	685--755′
Sandstone	71′ 6″	755′-826′ 6″
Coal	3′ 6″	826′ 6″-830′
Sandstone	15′	830′-845′
Shale	62′ 6″	845′-907′ 6″

Coal	2′ 6″	907′ 6″-910′
Sandstone	100′	910′-1,010′
Coal	1′ 6″	1,010′-1,011′ 6″
Sandstone	96′ 6″	1,011′ 6″-1108′
Coal	2′	1,108′-1,110′
Sandstone	100′	1,110′-1,210′
Black Shale	88′	1,210′-1,298′
White Sandstone	5′	1,298′-1,303′
Black Shale	37′	1,303′-1,340′
White Sandstone	61′	1,340′-1,401′
Black Shale	54′	1,401′-1,455′
Sandstone	54′	1,455′-1,509′
Black Shale	21′	1,509′-1,530′
White Sandstone	37′	1,530′-1,617′
Slate and Shale	60′	1,617′-1,677′
White Sandstone	12′	1,677′-1,689′
Slate and Shale	23′	1,689′-1,712′
White Sandstone	5′	1,712′-1,717′
Shale	72′	1,717′-1,789′
White sandstone (base of Lee)	47′	1,789′-1,830′
Chester Shales	270′	1,830′-2,100′
St. Louis Limestone	840′	2,100′-2,940′

Two miles east of the Todd wells, there is a well drilling on a branch of Black Wolf Creek and eight miles east there is one drilling on Brimstone. Both of these have encountered many obstacles and the drilling has been much delayed. The drillers are now actively at work on these wells and it seems that they will soon be pushed to completion.

Six miles southeast of Glenmary, on a branch of Cowan Creek, a well has recently been drilled on the G. A. Chandler farm to a depth of 2,090 feet. The elevation of the well mouth is approximately 1,350 feet. The base of the Lee formation was reached probably at 1,040 feet, though the material between there and 1,100 feet is not entirely diagnostic and may also belong to the Lee. If so, the base of the Lee is at 1,100 feet, for the next item of the log is fifty feet of limestone and then comes typical Pennington Red Shale. The top of the St. Louis, or Newman, limestone is at 1,305 feet. From the log as given to the Survey, it seems that the Chattanooga Black Shale was not quite reached at 2,090 feet. A little gas was gotten at 1,608 feet and more gas, with a show of oil, at 1,985 to 2,025 in a white limestone. The gas was estimated at 100,000 feet. The well was plugged and abandoned.

At Sunbright a well has been drilled on the S. H. Jones farm. The elevation of the well mouth is between 1,360 and 1,365 feet and the well ended at 1,725 feet after passing through what is believed to be the Chattanooga Black Shale at 1,678 to 1,695 feet depth. The detailed log, although at hand, is not available for publication. The well obtained several shows of oil and gas.

A well has recently been drilled near Wartburg and another is now drilling in the same vicinity. So far, it has not been possible to secure detailed information concerning these wells. The one that has been completed is reported to be a dry hole.

From all that has been learned of the wells so far drilled in the Glenmary region, a number of facts seem clearly established:

First, The oil comes from fissures in the St. Louis, or Newman, limestone. These fissures are not at exactly the same stratigraphic level in even adjacent wells, but may vary as much as fifty or seventy-five feet up or down.

Second, The limestones are not fissured everywhere. One well may find an unusually open set of fissures, such as those encountered by the Anna Pemberton No. 1, while the next well may find the limestone entirely without fissures.

Third, Near-by wells may be entirely independent of each other or may show that the fissures are connected so that the pumping of one affects the other.

Fourth, Wells usually show some gas. This varies greatly in amount. The largest well so far, yielded two and one-fourth million feet when gaged. The gas in one of the largest wells is wet with oil.

Fifth, There is little, or no water reported anywhere in the St. Louis limestone, or in any of the deeper rocks.

Sixth, The general structure of the region is that of a monocline rising gently westward, and the distribution of the oil in the St. Louis limestone does not appear to be dependent on any terraced or anticlinal structure, but on the presence or absence of fissured zones in the massive St. Louis limestone. The largest gas wells, those southwest of Rugby Road, are in rocks that are structurally higher than at any of the wells that have produced oil, except the Stonecipher well.

Seventh, A well will suddenly go dry as several have done, when the oil in the system of fissures tributary to it, has been exhausted. If these fissures have tide ramification through the rock, the area

drawn upon may be much larger and the life of the well be much more permanent. A few of the oldest wells, like the Pemberton No. 1 and the Todd Nos. 1 and 3, have in this way maintained a steady production of five or six barrels for a year or more, and show no signs of final exhaustion.

Eighth, Further drilling to the east and west will soon determine the conditions in these directions and throw much light on the possibilities of extending the field. If the St. Louis limestone can anywhere be found through slight, localized disturbance or other causes, such as dolomitization, to be more generally and uniformly fissured, it may be expected to furnish a pool with such staying qualities as would make it attractive to develop. The surface rocks have so far failed to show any such disturbance and if highly fissured areas exist in the St. Louis limestone, they apparently must be discovered by the drill and not by surface exploration. Unfissured areas in the St. Louis are numerous enough, as shown by dry holes, to increase considerably the hazard of such drilling.

Publications of Geological Survey of Tennessee Issued.

The following publications have been issued by the present Survey, and will be sent on request *when accompanied by the necessary postage.*

BULLETIN No. 1—Geological Work in Tennessee.

A. The establishment, purpose, object and methods of the State Geological Survey; by Geo. H. Ashley, 33 pages, issued July, 1910, postage, 2 cents.

B. Bibliography of Tennessee Geology and Related Subjects; by Elizabeth Cockrill, 119 pages; postage, 3 cents.

BULLETIN No. 2—Preliminary Papers on the Mineral Resources of Tennessee, by Geo. H. Ashley and others.

A. Outline Introduction to the Mineral Resources of Tennessee, by Geo. H. Ashley, issued September 10, 1910; 65 pages; postage, 2 cents.

D. The Marbles of East Tennessee, by C. H. Gordon; issued May, 1911; 33 pages; postage, 2 cents.

E. Oil Development in Tennessee, by M. J. Munn; issued January, 1911; 46 pages; postage, 2 cents.

G. The Zinc Deposits of Tennessee, by S. W. Osgood; issued October, 1910; 16 pages; postage, 1 cent.

BULLETIN No. 3—Drainage Reclamation in Tennessee; 74 pages; issued July, 1910; postage, 3 cents.

A. Drainage Problems in Tennessee, by Geo. H. Ashley; pages 1-15; postage, 1 cent.

B. Drainage of Rivers in Gibson County, Tennessee, by A. E. Morgan and S. H. McCrory; pages 17-43; postage, 1 cent.

C. The Drainage Law of Tennessee; pages 45-74; postage, 1 cent.

BULLETIN No. 4—Administrative Report of the State Geologist, 1910; issued March, 1911; postage, 2 cents.

BULLETIN No. 5—Clays of West Tennessee, by Wilbur A. Nelson; issued April, 1911; postage, 4 cents.

BULLETIN No. 9—Economic Geology of the Dayton-Pikeville Region, by W. C. Phalen; issued May, 1911; postage, 4 cents.

BULLETIN No. 10—Studies of the Forests of Tennessee.

A. An Investigation of the Forest Conditions in Tennessee, by R. Clifford Hall; issued April, 1911; 56 pages; postage 3 cents.

B. Chestnut in Tennessee, by W. W. Ashe, issued December, 1911; postage, 2 cents.

C. Yellow Poplar in Tennessee, by W. W. Ashe, issued January, 1914; 55 pages; postage, 3 cents.

BULLETIN No. 13—A Brief Summary of the Resources of Tennessee, by Geo. H. Ashley; issued May, 1911; 40 pages; postage, 2 cents.

BULLETIN No. 14—The Zinc Deposits of Notheastern Tennessee, by A. H. Purdue; issued September, 1912; 69 pages; 30 illustrations; postage, 3 cents a number.

BULLETIN No. 15—Administrative Report of State Geologist, 1912.

BULLETIN No. 16—The Red Iron Ores of East Tennessee, E. F. Burchard; issued November, 1913; 172 pages; postage, 8 cents.

BULLETIN No. 17—The Water Powers of Tennessee, by J. A. Switzer; issued April, 1914; 137 pages; postage, 8 cents.

BULLETIN No. 18—Administrative Report of the State Geologist, 1914.

BULLETIN No. 19—Elevation in Tennessee, by Elizabeth Cockrill; issued 1917, 80 pages; postage, 3 cents.

MAPS—Map of Lewis County, 1915; postage, 2 cents.
Geological Map of Tennessee, 1915; postage, 15 cents.
Map of Rutherford County, 1916; postage, 2 cents.
Map of McNairy County, 1916; postage, 2 cents.

"THE RESOURCES OF TENNESSEE"—This is a quarterly magazine, devoted to the description, conservation and development of the State's resources. Postage, 2 cents a number. The following are the volumes and numbers issued, with the title of the principal papers in each number:

Vol. I. No. 1—The utilization of the small water powers in Tennessee, by J. A. Switzer and Geo. H. Ashley. (Out of print).

No. 2—The Camden chert—an ideal road material, by Geo. H. Ashley.
The Fernvale iron ore deposit of Davidson County, by Wilbud A. Nelson.
Cement materials in Tennessee, by C. H. Gordon.
(Out of print).

No. 3—The gold field of Coker Creek, by Geo. H. Ashley.

No. 4—Coal resources of Dayton-Pikeville area, by W. C. Phalen.

No. 5—Economic aspects of the smoke nuisance, by J. A. Switzer.
Watauga Power Company's hydro-electric development, by Francis R. Weller.
The coal fields of Tennessee, by Geo. H. Ashley.

No. 6—Bauxite Mining in Tennessee, by Geo. H. Ashley.
A New Manganese Deposit in Tennessee, by Wilbur A. Nelson.
Road Improvement in Tennessee, by Geo. H. Ashley.

Vol. II. No. 1—The Utilization of the Navigable Rivers of Tennessee, by Geo. H. Ashley.
Dust Explosions in Mines, by Geo. H. Ashley.
The Rejuvination of Wornout Soil Without Artificial Fertilizers, by Geo. H. Ashley.
Tennessee to Have Another Great Water Power, by George Byrne.
Manufacture of Sulphuric Acid in Tennessee in 1911, by Wilbur A. Nelson.

No. 2—The Ocoee River Power Development, by J. A. Switzer.
Exploration for Natural Gas and Oil at Memphis, Tenn., by M. J. Munn.

No. 3—The Power Development at Hale's Bar, by J. A. Switzer.
Notes on Lead in Tennessee, by Wilbur A. Nelson.

No. 4—The Tennessee Academy of Science.
The Preliminary Consideration of Water Power Projects, by J. A. Switzer.
Lignite and Lignitic Clay in West Tennessee, by Wilbur A. Nelson.

No. 5—The Growth of Our Knowledge of Tennessee Geology, by L. C. Glenn.

No. 6—On the Impounding of Waters to Prevent Floods, by A. H. Purdue.
Drainage Problems of Wolf, Hatchie, and South Fork of Forked Deer Rivers, in West Tennessee, by L. L. Hidinger and Arthur E. Morgan.
The Waste from Hillside Wash, by A. H. Purdue.

No. 7—Where May Oil and Gas Be Found in Tennessee? By Geo. H. Ashley.
Spring Creek Oil Field, by M. J. Munn.

No. 8—The Monteagle Wonder Cave, by Wilbur A. Nelson.
Cave Marble (Cave Onyx) in Tennessee, by C. H. Gordon.

.No. 9—The Valley and Mountain Iron Ores of East Tennessee, by Royal P. Jarvis.

No. 10—The Iron Industry of Lawrence and Wayne counties, by A. H. Purdue.
Some Building Sands of Tennessee, by Wilbur A. Nelson.

No. 11—Tests on the Clays of Henry County, by F. A. Kirkpatrick. Introduction by Wilbur A. Nelson.
Barite Deposits in the Sweetwater District, by Herbert B. Heneger.

No. 12—The Soils and Agricultural Resources of Robertson County, by Reese F. Rogers.
The Iron Ore Deposits in the Tuckahoe District, by C. H. Gordon and R. P. Jarvis.

Vol. III. No. 1—The General Features of the Tennessee Coal Field North of the Tennessee Central Railroad, by L. C. Glenn.
The Tennessee Coal Field South of the Tennessee Central Railroad, by Wilbur A. Nelson. (Out of print).

No. 2—State Supervision of Forestry, by L. C. Glenn.
Conservation of the Water Powers of Tennessee, by J. A. Switzer.
Water Supplies for Cities and Towns, by A. H. Purdue.
Types of Iron Ore Deposits in Tennessee, by C. H. Gordon.
The Causes and Nuisance of Smoke, by Wilbur A. Nelson.
Geology and Engineering, by A. H. Purdue.

No. 3—The Gullied Lands of West Tennessee, by A. H. Purdue.
White Rock Phosphate of Decatur County, Tennessee, by T. Poole Maynard.
Mineral Products Along the Tennessee Central Railroad, by Wilbur A. Nelson.
Relations of Water Supply to Health, by J. A. Switzer.

No. 4—Minerals of Tennessee, Their Nature, Uses, Occurrence and Literature, by A. H. Purdue.
Building Precautions Against Earthquake Disasters, by Olaf P. Jenkins.

Vol. IV. No. 1—Relation of Water Supply to Health, by J. A. Switzer.
Earthquakes in East Tennessee, by C. H. Gordon.
The State Geologist and Conservation, by A. H. Purdue.
A Tripoli Deposit Near Butler, Tenn., by L. C. Glenn.

No. 2—The Brown and Blue Phosphate Deposits of South-Central Tennessee, by J. S. Hook.
Discussion, Lucius P. Brown.
Bauxite in Tennessee, by A. H. Purdue.

No. 3—Economic Geology of the Waynesboro Quadrangle, by N. F. Drake.
Recent Water Power Development in Tennessee, by J. A. Switzer.
Two Natural Bridges in Tennessee, by Hugh D. Miser.
Road Materials of Tennessee, by A. H. Purdue.
Report on the Water Powers of Tennessee.

No. 4—The Need of a Soil Survey of Tennessee, by C. A. Mooers.
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Indexes to Volumes III and IV.

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OCTOBER, 1918

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G. W. Stose and F. C. Schrader

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Manganese Deposits of East Tennessee (Part II)
G. W. Stose and F. C. Schrader

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11. Map of East Tennessee in two parts (A and B), showing location of manganese mines and prospects.....opposite pages 234 and 236

12. Geological map of the Red Hills near Sweetwater, Tenn.....opposite page 304

13. Geologic map of the Red Hills area southeast of Cleveland, Tenn.....opposite page 316

14. Sketch section of the pit of the Lord mine 321

Errata and Addenda to Part I.

Due to the fact that Part I of this paper was not seen in proof by the authors, several errors, some quite serious, have crept into the report and should be here corrected.

Both the cover and title page. The author's name should be F. C. Schrader, not F. G.

Figure 1, frontispiece, and figure 4, page 169. The bar scale should read 10 in place of 1, and 20 in place of 2. The scale should be 27½ miles to the inch in place of 2¾ miles.

Page 153, 9th line, 1st word, substitute material for mineral.

Page 161, 3rd line, Manganese, used twice, should read manganite.

Page 161. Add description as follows:

Braunite. Braunite ($3Mn_2O_3.MnSiO_3$) is a heavy nearly black mineral generally massive crystalline in form, streak brownish black, hardness 6 to 6.5, specific gravity 4.75, cleavage perfect. It may be distinguished from psilomelane by its browner streak, crystalline cleavage faces in the broken or polished rock, and slightly greater hardness. It is considerably harder than manganite, which also has a black streak. However, any of these minerals when weathered or impure may have a brownish streak and may be softer than the typical mineral, so that it is not always easy to distinguish them. Braunite has not certainly been identified in the minerals from East Tennessee, but bright cleavage faces in the dense psilomelane ore from several places mentioned in the descriptions are believed to be those of braunite.

Page 180, figure 5. The note below cut should read: Floor of mine is composed of brecciated sandstone impregnated with manganese ore. Scale, about 1 inch=2 feet, should be added.

Page 182, 3rd line, 5th word, should be trend instead of trench.

In the table on pages 167 and 168 and the accompanying pages of description the names of formations printed in the folios of the Geologic Atlas of the U. S. Geological Survey covering East Tennessee are used. From the fossils collected and the stratigraphic relations in the field recently observed by G. W. Stose and E. O. Ulrich in revising the geologic maps of the Red Hills area around Sweetwater and

Cleveland (Figs. 12 and 13) the following conclusions with regard to the Sweetwater-Cleveland area have been reached: The limestone called Chickamauga limestone is Lenoir,[1] named by Safford after the town of Lenoir in this area; the Holston marble, which is apparently continuous with the Holston marble of the Knoxville area, appears to be equivalent to the lower part of the Tellico formation in the more eastern belts, and may prove not to be of Holston age; the Tellico sandstone, which is here more calcareous and much thinner than in the more eastern belts, represents a marked change in the character of the sediments by the influx of red sands from former lands to the southeast, and although there may be no great unconformity at its base the abrupt change in sediment and the irregularity of its base in part filling channels between reefs, are evidence of unconformable relations at least within the formation. The Tellico sandstone as properly restricted is not the equivalent of the Moccasin limestone as stated in the table, but is older; the Sevier shale, including yellow shales, shaly limestones, and marbles, is equivalent to the Ottosee[1] shale of Chazyan age. The names employed in the geologic folios are, however, used throughout the folloiwng descriptions.

A composite section of the rocks exposed in the Sweetwater-Cleveland area is as follows, thicknesses being only estimated:

[1]The names Lenoir limestone and Ottosee shale are in current use but have not yet been adopted by the U. S. Geological Survey. They are fully described by Mr. Ulrich in Bull. Geol. Soc. of Amer., Vol. 22, 1911.

	Feet	
Sevier shale (Ottosee shale of Ulrich)	10+	Soft reddish porous sandstone, formerly calcareous, carrying a small amount of hematite of no economic value, and prospected for iron at one place southeast of Cleveland.
	20+	Siliceous gray oolitic marble, reddish in part.
	40+	Shaly gray limestone.
	60+	White marble, mostly coarse granular, some fine saccharoidal. Reddish blotched and pink beds in lower part. Somewhat fossiliferous throughout.
	40+	Gray to greenish shaly limestone, very fossiliferous.
	50+	Soft greenish calcareous shales, weathered yellow, and some very fossiliferous shaly limestone at the base. The basal beds fill depressions and solution channels 20 or more feet deep in the upper surface of the underlying marble, representing a marked unconformity.
Tellico sandstone	90+	Coarse granular crinoidal red marble with bryozoa and coral reefs in the upper part.
	50	Pink crinoidal granular marble with crossbedded siliceous and ferruginous banding and small shiny hematite-coated pebbles. The ferruginous layers are workable ore beds in places, especially where the ore is concentrated in solution pockets in the underlying marble. Toward the southwest, yellow shale at one or more horizons is present in considerable quantity.
Holston marble	30	Thick-bedded pink marble with deep black stilolitic markings.
	10	White marble, in part light greenish, mostly coarse granular, but in part fine grained.
Chickamauga limestone (Lenoir limestone of Safford and Ulrich)	100+	Thin-bedded blue limestone with wavy partings.
Knox dolomite		Fine-grained even bedded light-gray dolomite and magnesian limestone.

Mention should be made of the important fact that the old land surfaces of past ages had much to do with the accumulation and concentration of nearly all the manganese ore deposits of whatever type. The deposits are dependent on deep weathering of the associated rocks, for the minerals are first dissolved from the weathering rock and are later deposited where there are deep soils and accumulation of waste material through which the solutions percolate. Therefore old level land surfaces, such as the bottoms of old valleys, which were the dumping ground of waste material from higher ground and were uneroded for long periods of time except by subsurface solution because of the stability of land conditions, afforded favorable places for the deposition of ores. Later erosion has cut the present valleys into these old valley floors and left their remnants as benches on the sides of the valleys or as isolated ridges and knolls, generally covered with deep soil and weathered rock debris, and in places deeply covered with mountain wash. Most of the ore deposits herein described will be found to occupy such positions.

The list of manganese mines and prospects on pages 199--207 should be corrected as follows:

Johnson County, Davis prospect (same as Neely mine) change to read 6 miles northeast of Crandull.

Hamblen County, Lotspeich prospect, change to read 3 miles northwest of Morristown.

Monroe County, Vita mine, change to read Vida mine, C. D. Smith owner, Vida Iron Co. operator. (The adjoining Ewing mine, owned by Robert Ewing, was operated by Fitzgerald & Smith.)

Monroe County, Kimbrough prospect, change to read 2 miles to Louisville & Nashville Railroad.

Monroe County, Groundhog Mountain prospect, change to read J. H. Curd operator.

Additions to the list of mines and prospects should be made from the list on the map (Fig. 11) and descriptions in the text.

Manganese Deposits of East Tennessee

PART II.

By G. W. Stose and F. C. Shrader.

Description of Mines and Prospects.[1]

The manganese mines and prospects of East Tennessee, 116 or more in number, lie chiefly in a narrow northeast-southwest belt about 220 miles long extending diagonally across the State near its eastern border. A few unimportant deposits in Grainger County lie outside the belt to the northwest. The location of the mines is shown on the accompanying map (Fig. 11, A and B). Iron, lead, and zinc ores, pyrite, barite, marble, bauxite, kaolin, fluorite, limestone for flux, and phosphate are also mined in the belt, mostly on a small scale, however.

The mines and prospects will be described by counties in geographical order beginning with Johnson County at the Virginia State line in the northeast corner of the State. Manganese ore is known to occur in minable quantities in 17 counties, which are given in the following list in the order in which they are described.

Counties in which commercial manganese deposits occur in East Tennessee.

Johnson,	Washington,
Carter,	Greene,
Unicoi,	Cocke,

[1]This report, which is the second part of the report on the Manganese Deposits of East Tennessee by G. W. Stose and F. C. Schrader, was prepared under a co-operative agreement between the State Geological Survey and the United States Geological Survey, the latter bureau being represented by Messrs. G. W. Stose and F. C. Schrader. Mr. Arthur C. McFarlan, who represented the State Geological Survey, visited certain prospects and made the detailed maps of the Sweetwater and Cleveland districts (Figs. 12 and 13, opposite pages 304 and 316), the geological boundaries of which have been somewhat modified by Stose in the field.

The descriptions of the mines are based chiefly on the examination of the deposits by Stose and Schrader during a field trip in April to June, 1918, and short trips by Stose in October, 1917, and by Stose and Schrader in October, 1918.

Grainger,	Blount,
Hamblen,	Loudon,
Jefferson,	Monroe,
Sevier,	McMinn,
Knox,	Bradley.
Anderson,	

Each description will include the location of the deposit, the extent of development of the mine, a brief account of the plant, the character and association of the ore, and its geologic relations. The probable extent of the ore and suggestions for further prospecting will be also given where warranted.

The deposits as a whole are estimated to contain 85,000 tons of ore available under present conditions, of which 75,000 tons is classed as manganese ore, but includes some ferruginous manganese, and 10,000 tons as manganiferous iron ore. To obtain these figures an estimate was made at each mine and prospect of the ore proven by prospecting and by geologic relations to be present and so accessible that it can be profitably mined at the present market prices. The total estimate is therefore conservative.

By the term manganese ore is meant ore that contains 35 per cent or more of metallic manganese. Ferruginous manganese ore contains from 10 to 35% of manganese and a percentage of iron commonly varying from 10 to 40. Manganese ore is used in the manufacture of ferromanganese. Ferruginous manganese ore is generally used in the manufacture of spiegeleisen but in some plants is mixed with higher-grade ores from which ferromanganese is made. The lower grades of ferruginous manganese ore are also used in making manganiferous pig iron. Iron ore that contains less than 10% and more than 1% of manganese is termed manganiferous iron ore. It is used in the manufacture of manganiferous pig iron, but does not have an increased value due to its manganese content.

(For table of Production of Manganese Ores in Tennessee, see page 324.)

The schedule of market prices of manganese ores in the United States fixed by the War Industries Board and the American Iron and Steel Institute[1] in June, 1918, is as follows:

[1]Engineering and Mining Journal, vol. 105, No. 23, p. 1053, June 8, 1918.

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UNIV. OF MICH.

Schedule of prices for manganese ore.

Metallic manganese content. Per cent.	(Dried at 212° F.) Price per unit f.o.b. South Chicago.		Average price per ton. (2240 lbs.)	
	Mined east of S. Chicago	Mined west of S. Chicago	Mined east of S. Chicago	Mined west of S. Chicago
35 to 35.99	$1.01	$0.86	$35.85	$30.53
36 to 36.99	1.05	0.90	38.32	32.85
37 to 37.99	1.09	0.94	40.87	35.25
38 to 38.99	1.13	0.98	43.50	37.71
39 to 39.99	1.15	1.00	45.42	39.50
40 to 40.99	1.17	1.02	47.38	41.31
41 to 41.99	1.19	1.04	49.38	43.16
42 to 42.99	1.21	1.06	51.42	45.05
43 to 43.99	1.23	1.08	53.50	46.98
44 to 44.99	1.25	1.10	55.62	48.95
45 to 45.99	1.27	1.12	57.78	50.96
46 to 46.99	1.29	1.14	59.98	53.01
47 to 47.99	1.31	1.16	62.22	55.10
48 to 48.99	1.33	1.18	64.50	57.23
49 to 49.99	1.35	1.20	66.82	59.40
50 to 50.99	1.37	1.22	69.18	61.61
51 to 51.99	1.39	1.24	71.58	63.86
52 to 52.99	1.41	1.26	74.02	66.15
53 to 53.99	1.43	1.28	76.50	68.48
54 and over	1.45	1.30	78.30+	70.20+

Prices are based on ore containing not more than 8% silica and not more than .25% phosphorus. Premium of 50 cents per ton for each 1% silica under 8% down to 5%, and of $1 per ton for each 1% silica under 5%; penalty of 50 cents per ton for each 1% silica in excess of 8% up to 15%, of 75 cents per ton for each 1% silica in excess of 15% up to 20%, and of $1 per ton for each 1% silica in excess of 20% up to 25%. Ore containing over .25% phosphorus subject to penalty and bought at the option of the buyer.

JOHNSON COUNTY.

Johnson County, the northeasternmost county of the State, is largely mountainous, and it is becoming that its county seat is named Mountain City. Its western boundary follows the crest of Holston and Iron mountains, and its eastern boundary, here the State line, follows the crest of Stone Mountain in much of its course. Doe, Dry Run, and Iron mountains, and smaller ridges and spurs divide the county into several longitudinal northeastward trending valleys in which

manganese deposits occur. Description of the 27 manganese mines and prospects in this county follow.

SHADY VALLEY DISTRICT.[1]

Shady Valley is the flat-bottomed valley between Holston and Iron mountains which is drained northward by Beaverdam Creek in the northwestern part of Johnson County. Although the open valley ends a mile or so north of Crandull, where the stream enters a rocky gorge, the few mines and prospects lower down the creek near Sutherland will be included in the Shady Valley district.

Reynolds mine.[1]—The Reynolds mine is 1½ miles south of Damascus, Va., just south of the Virginia State line, and three-fourths mile northeast of Sutherland. The property is owned by A. D. Reynolds of Bristol. The Lehigh Valley Manganese Company, of Bethlehem, Pa., and Damascus, Va., have leased the property and began development in June, 1918. By October 100 tons of ore had been mined, about half of which had been shipped. It is reported to average 40% manganese, 13% silica. Over half of the ore is fines. Manganiferous iron ore was mined at the north end of the property many years ago.

The mine is on a terraced spur on the northwest slope of Iron Mountain, at an elevation of 2,400 feet, or 450 feet above the creek. It is in red and yellow clay, believed to be residual from the Shady dolomite, resting on Erwin quartzite. The structure may be locally synclinal, as the quartzite in the gulch to the north dips 40° S.

The deposit is opened by several cuts not over 10 feet deep and covering a vertical range of 50 feet on the slope. Most of them show nodular psilomelane wash ore in the clay, chiefly in the upper layers. Most of the ore is scattered in the clay, but irregular streaks and lenses also occur and show evidence of disturbance and movement by creep down the slope. A bed of soft ore about a foot in thickness was observed near the north end of the property. The indications are on the whole unfavorable.

The ore is sledded down the steep slope to the washer 230 feet below the mine and the washed ore is hauled in wagons to the railroad.

---

[1]Descriptions of most of the Shady Valley mines and prospects are by G. W. Stose.

[1]Description of the Reynolds, Neely, and Hogback mines are by F. C. Schrader after visit in October, 1918.

Neely Mine.—The Neely mine is one mile south of Sutherland on the east side of Beaverdam Creek, on the Government Forest Reserve. The manganese deposit was first opened by J. A. Neely, of Damascus. It is now being operated by the Laurel Mining Company, of Mountain City, in which the Southern Manganese Corporation holds one-third interest. It was worked about 1898 for iron ore. Twenty-seven tons of manganese ore, mostly from the old dumps, has recently been shipped and about four tons lie on the dump. The ore is dry-screened and is reported to run about 45% manganese, 4% silica when washed. A road from the mine to the railroad is to be built and a washer installed. The ore is at present hauled to the railroad on sleds.

The prospect is on a bench on the northwest slope of Iron Mountain, at 2,800 feet in elevation, 600 feet above the creek. It is in reddish-brown clay, probably residual from Shady dolomite, which rests on Erwin quartzite apparently dipping northwest into the Beaverdam syncline. The main opening is a 50-foot cut running northeast into the ridge, following an ore zone about 8 feet thick which dips 20° NNW. The pit is 20 feet wide and 15 feet high at the face. The ore is hard psilomelane in nodules and irregular mammillary fragments ranging up to a foot in diameter. Some wad and soft pyrolusite is also present. The ore shipped came from this pit, which is the original working reopened.

About 250 feet northeast of the main pit another old working is being reopened, and shows considerable scattered ore. It has been reported since the visit by the writer that a solid body of ore has been struck in this working. The prospects are bright for an active mine at this place.

Sutherland Prospect.—The Sutherland prospect is 1¾ miles southwest of Sutherland on lands of the U. S. Forest Reserve, which has recently been prospected under lease from the Government by Wiley and J. F. Sutherland, and the indications are reported to be exceptionally favorable. Geologic conditions are believed to be the same as at the Neely mine.

Hogback Mine.—The Hog back mine is 2½ miles south-southwest of Sutherland, on the Government Forest Reserve. It was first opened in 1888 by David Blevins, of Shady Valley, for William McGovern, of Pennsylvania. It has only recently been developed and is now operated by the Lehigh Valley Manganese Company, of Bethlehem, Pa., with an office at Damascus, Va. Operations began early in 1918, and

by October they had mined and shipped about 80 tons and had a like amount at the mine ready to ship. It is reported to run 42% manganese, 8% iron, 12% silica. It is at present dry-screened and hand-picked, and in part washed by hose in loading the cars by gravity, but a washer is to be constructed.

The mine is on a bench on the northwest slope of Iron Mountain, at an elevation of 2,900 feet, 650 feet above the creek. The deposit is in brownish and red clay, in part wash and in part residual from Shady dolomite, resting on Erwin quartzite, which apparently dips northwest into the Beaverdam syncline. It is opened by several cuts about 10 feet deep with a vertical range of 100 feet, all showing ore. The best exposure is in a cut 60 feet long. The ore is largely psilomelane in nodular botryoidal forms distributed in zones or layers several inches in thickness and also sporadically isolated. Some wad and pyrolusite are also present. None of the ore is very hard. The upper part of the clay is banded parallel with the surface, indicating creep and surface deposition. Float ore is found on the surface below the mine and also along the slope on the same level as the mine. The indications are regarded as favorable for successful mining.

Davis Mine.—The Davis mine, called also Parker, or Crandull, mine, is just west of Crandull at the lower end of Shady Valley. The openings are on a flat-topped spur on the west side of the valley 100 to 200 feet above the present valley bottom, adjacent to the site of the old Heberlin mine, from which 800 tons of manganese ore are reported to have been taken years ago.[1] Since the time of visit of the writer, October, 1917, the mine has been leased to the Southern Manganese Corporation and is at present being actively operated by them.

The property was developed by George E. Davis, of Bristol, Va., who opened several pits and shipped a carload of ore, which is reported to have run about 43% manganese. The lower openings, on the outer edge of the terrace about 100 feet above the valley bottom, are on E. N. Martin's land and are shallow pits in yellow clay and dark manganiferous clay, showing considerable high-grade crystalline manganese ore, probably manganite, and some iron ore. Most of the manganite is cellular, forming the partitions of cells, some of which are now empty. The clay is residual from impure calcareous beds of the Shady dolomite lying just above soft red and green glau-

[1]Harder, E. C., U. S. Geol. Survey Bull. 427, 1910, p. 74.

conitic sandstones and about 70 feet above the coarse sandstone of rounded quartz grains at the base of the Shady which outcrops on the slope below in nearly horizontal position. The face of one small pit was almost solid ore, and although considerable ore is iron, the quantity of high-grade manganese ore from the pit looked very promising. Float ore and dark-brown soil above the pits indicate the probable extension of the deposit over most of the surface of the terrace, which is part of the old valley floor.

The higher prospects are a short distance farther back on the terrace, across a small ravine, on W. J. Parker's land. In June, 1918, this property was leased to the Southern Manganese Corporation, which is equipping it with machinery and will begin active operation at once. The tract includes the pits of the old Heberlin mine, whose waste dump contains sufficient nodules of psilomelane to be reworked and profitably washed. The new pits are dug into the side of the ravine about 20 feet below the top of the terrace and show excellent ore, largely psilomelane in stalactitic form, with crystalline manganite lining cavities and covering the stalactites. The best exposure showed the ore inclosed in wad and dark manganiferous clay, capped by a nearly horizontal layer of hard manganiferous brown-iron ore. Several tons of high grade lump ore in large masses lay on the dump of this small pit and the face of the pocket was still in ore. Several small pits farther up the ravine showed the ore to extend 100 feet or more back on the terrace. Analysis of a carload of the better grade ore shipped during 1917 ran 45.18% manganese, 9.77% iron, and 6.27% silica. A carload of ferruginous manganese ore from the caprock, also shipped in 1917, ran 20.17% manganese, 27.10% iron, and 13.94% silica.

The mine is near the end of a gentle minor syncline on the side of the larger Shady Valley syncline. The dips of the rocks are nearly flat and the geologic conditions are unusually favorable for the accumulation of ore. The quantity and high grade of the ore in the prospects also support this view. These favorable conditions probably extend northeastward on the terraced spurs, where some prospecting has been done, and also southwestward where there has been no prospecting so far as known. The thick layer of wash from the mountain slope which covers most of the terraced spurs makes prospecting difficult.

The mine has recently (October, 1918) been visited by Mr. Schrader, who reports marked activity. Lodging and commissary buildings to accommodate 80 men are nearing completion. The washer and pumping plant have been erected and electric lights are being installed so that the washer can be run day and night in two shifts. The present production of 16 tons of washed ore a day it is planned to increase to 40 tons. The dirt is removed by mule plows and scrapers, dumped through a trap door to undershot tram cars and conveyed by gravity over a double track trestle to the 25-foot double-log washer 60 feet from the lower end of the mine, where it is dumped by the tilting of the car. The washed ore is hauled by wagon to the railroad at Crandull. The pumping plant is at Crandull, on Beaverdam Creek, and has a capacity of 300 gallons a minute.

The face of the working is 30 feet high and shows good ore throughout, except for about 12 feet of lean overburden and some barren clay, which is removed by scrapers into the gulch below. The run of mine dirt concentrates 12 into 1. About 40% of the ore is fines, as so much of the ore is brittle crystalline manganite, and tables may be installed to reduce the silica, although this is generally done at the company's plant in Anniston. The ore shipped is reported to run 41% manganese, 10% iron, and 8% silica. The development work has been well planned by the company's engineers, and if the deposit proves as large as is hoped, the use of a steam shovel and other enlargements of the plant will also be made.

King Prospect.—Several small pits have been opened on the King property west of Shady village, in the upper part of Shady Valley, where several old abandoned ore banks occur. These are on a low terrace about 20 feet above the flat valley floor. The pits are in clay residual from the lower dolomite beds of the Shady, and apparently occupy a minor gentle syncline within the Shady Valley syncline, as the coarse porous sandstone layer at the base of the Shady dolomite outcrops in the axis of a small anticlinal fold about one-half mile to the south. On what is called the Five Acre tract at the north end of the property psilomelane nodules occur sparingly in dark manganiferous clay beneath a 2-foot layer of brown-iron ore, which was formerly mined for iron, but the amount of manganese ore appears to be insufficient to be mined profitably. Dolomite is exposed in the lower part of the pit. The pits had been abandoned some time when visited.

Only old slumped pits were to be seen at the south end of the property, but since the time of visit it is reported by Miss M. E. King, of Danville, Va., that ten shafts have been sunk at this place and ore having an average analysis of 49.80% manganese, with a premium for low silica, was abundant. The samples submitted to the writers were good-sized chunks of clean solid ore, largely crystalline manganite. From these samples the prospect appears very favorable and should be developed at once before the lumber railroad which now runs to the property is removed. The Southern Manganese Corporation has examined it and is understood to have been favorably impressed with it.

Maxwell Mine.—The Maxwell mine is located one mile northwest of Shady village, in the upper part of Shady Valley, on a tract of land of which the mineral right only is owned by the Maxwell Manganese Mining Company, of Elizabethton, Tenn. H. V. Maxwell, its president, was personally developing the tract at the time of visit, and a carload of washed ore was nearly ready for shipment to determine its grade and value. Considerable manganiferous iron ore had also been taken out, but the cost of transportation was such that it could not be shipped with profit. Iron ore had been mined on the property many years ago by Mr. Scott for a local forge.

The property is developed chiefly by two shallow trenches in a small stream bottom on the west side of the valley. This deposit is largely in clay and sand wash from the adjacent hillside which overlies residual clay of the Shady dolomite. Considerable ore was showing in pockets in the face of the pits, but water from the stream had flooded the pits and temporarily stopped the work. The deposit is badly located in this respect for economic handling. The ore is chiefly psilomelane, some of which is stalactitic, and occurs in irregular pockets in the yellow clay beneath a capping of manganiferous iron ore and in the iron ore itself. One specimen contained clear transparent rhombohedral crystals of siderate in cavities in the psilomelane. The ore was being washed by hand in a trough or sluice box in the stream, and the fines were therefore rather siliceous.

Several prospect pits were being opened on the top of the terrace just north of and 100 feet above the mine, which forms part of the old valley floor now deeply cut into by the present streams. These pits are in the clay residual from the Shady dolomite which directly overlies the coarse sandstone and purplish and greenish glauconitic

shaly sandstone of the basal part of the Shady. The rocks dip about 5° SE toward the valley on the west side of the flat Shady Valley syncline. There was plentiful dark manganiferous clay in these pits, but not much hard ore was struck. Some soft nodular manganese ore of very light weight occurs in the clay which so closely resembles plumbago in its greasy feel and shiny streak that it is readily mistaken for that mineral. It is a form of soft pyrolusite apparently derived from nodules of radiate needle manganite, and although a high grade ore, it is too scattered to be saved. The quantity of ore exposed in these pits at the time of visit was insufficient to warrant mining.

Wright Mine.—A half mile south of the Maxwell mine is the old Wright bank, where 150 tons of manganese ore were reported to have been mined some years ago.[1] It had recently been opened again by the Maxwell Manganese Mining Company, which shipped two carloads of ore during 1917.

The deposit is opened by a pit about 20 feet square into the face of a terrace 100 feet above the valley bottom. The ore consists of an irregular layer of manganiferous iron at the base of 5 feet of surface wash, which rests on pink to white and yellow plastic clay, apparently residual from Shady dolomite, in which no ore occurs, although tested to a depth of 25 feet. The ore is a brown-iron ore so seamed and veined with psilomelane and crystalline manganite as to resemble a breccia in appearance. A carload of selected manganiferous-iron ore is said to have run 52% iron and 16% manganese, but the general run of such ore would be much less, probably not over 48% iron and 10% manganese. A carload lot of hand-cobbed manganese ore from the old ore dump ran 30.8% manganese, 6.18% silica, and iron undetermined. Although the ore bed is 6 feet thick in places, the deposit will probably prove unprofitable to work because of its general low manganese content and the irregular occurrence of the better grade ore in pockets.

Osborn and Hopper Prospects.—A small pit showing some psilomelane ore has been opened on Aleck Osborn's property about one-half mile south of the Wright bank. The ore was exposed in a stream bank on the side of a wash-covered bench well up on the west

[1]Harder, E. C., Op. Cit., p. 74.

side of the valley. The pit was too small to show relations or quantity of ore.

A short distance farther south openings have been recently made by George Davis, of Bristol, on the Hopper property adjacent to an old iron bank mined years ago and close to the old manganese pit of Alexander Cole. Good ore was thrown out, but the pit had caved in and relations could not be determined.

Both of these prospects are underlain by clay residual from the lower part of the Shady dolomite, but whether the ore lies in this clay or only in the surficial wash was not determinable from the poor exposures.

MOUNTAIN CITY DISTRICT.

The Mountain City district embraces the valley area between Iron and Stone mountains north of Mountain City, followed by the Laurel Railroad, and the valley area around Mountain City. The open valley of Roane Creek as far as Neva station and that of Doe Creek as far as Doeville will be included, as these valleys are most easily reached from Mountain City, although the Doe Valley mine ships by way of Doe station near Butler.

Taylor Valley Mine.—The Taylor Valley mine, also called Reece mine, is in the northeastern part of the county at Matney, 10 miles north-northeast of Mountain City and two miles east of Dollars Station on the Laurel Railroad. It is on the I. H. Reece property and is operated by the East Tennessee Mining Company, of which H. A. Donnelly, of Mountain City, is secretary.

The deposit occurs in the Shady dolomite along a fault by which the pre-Cambrian volcanic rocks are thrust from the east on to the dolomite. The mine is described in detail as one of the types of manganese deposits in Part I of this paper (Res. of Tenn., Vol. VIII, No. 3, pp. 190-192).

Recent reports from the mine state that an opening on the northeast side of the spur opposite the older workings and at about the same elevation had exposed an ore body 12 feet thick opened for a length of 50 feet, which runs one-third ore of 40% manganese. This ore lies along the fault plane observed in the older deep pit, and probably is continuous through the ridge. The new pit is worked by mule plows and scrapers, the dirt being dumped into undershot tram cars on tracks leading around the end of the hill to the head of

the flume. The production has thereby been increased to 60 tons a month.

Silver Lake Mine.—The Silver Lake mine is in the north central part of the county at Silker Lake station, on the Laurel Railroad, five miles north of Mountain City. The property is owned by the N. F. Sutherland heirs, of Silver Lake, and the mine is operated by the Silver Lake Mining Company, of Mountain City. The ore deposits occur in terraced stream gravels which lie on Watauga shale. Analyses of the better grade ores shipped in 1917 and 1918 ran 42 to 45% manganese, 6 to 7% iron, 3 to 8% silica. Shipments of lower grade fines ran 25% manganese, 18% iron, 14% silica. It is planned to supplement the washer with jigs to improve the grade of the finer ore. The mine is described in detail as one of the types of manganese deposits in Part I of this paper (Res. of Tenn., Vol. VIII, No. 3, pp. 193-194).

Wills Mine.—The Wills mine is located near the north-central part of the county, a mile east of Wills station on the Laurel Railroad, and four miles northeast of Mountain City. It is owned by Oscar Wills, and is being worked by the Laurel Mining Company, of Mountain City. The company began operations April 10, 1918, and since that date has shipped several carloads of ore averaging about 40% in manganese and 15% in iron. The mine has recently been sold to the American Minerals Company, of Cincinnati, which is enlarging the plant.

The mine is at the west end of a low flat-topped hill or low terrace, whose surface was probably once part of the valley floor. This is underlain by Shady dolomite, which in general dips northward away from a hill of Cambrian quartzite southeast of the mine, but on the slope just below the mine it is horizontal. The deposit is chiefly in the surface wash and may pass down into the underlying residual clay of the Shady dolomite. It is opened by several pits to a maximum depth of 20 feet, but there are two main pits on opposite sides of the hilltop in a N 35° W direction, which may be the trend of the deposit.

The walls of the pits expose a thickness of 5 to 15 feet of surface wash of reddish-brown clay and quartzite fragments overlying yellow to brownish-buff and blackish residual clay. The ore lies chiefly in the lower part of the wash and in the residual clay just below.

The ore is chiefly psilomelane and occurs in nodules and lumps, some of large size, sporadically embedded in the clay and wash. One

lump 2½ feet in diameter was seen in one pit and another lump is reported to have yielded a ton of good-grade ore. Some of the nodules have a thin coating of red iron ore and are classed as ferruginous manganese ore.

The ore is treated in a double-log washer at the foot of the hill and is sorted into several grades and sizes, of which the best grade, or lump ore, contains about 45% manganese, the medium grade 35%, and the screenings, which were so sandy that they need further treatment before shipment. Ferruginous manganese ore containing about 25% manganese and 25% iron is also present. The average production is about four tons of ore a day derived from 40 tons of run-of-mine dirt put through the washer, a concentration of 10 into 1.

Silver Lake and Wills Prospects.—Several prospects have been opened on the Oscar Wills farm. The Silver Lake Mining Company has three shallow pits on a low terrace a few hundred yards northwest of the Wills mine, just across a small ravine. The pits are in surface wash containing some rather siliceous manganese ore which may improve in quality with depth if the ore continues into the underlying residual clay of the Shady dolomite. The pits covered a length of more than 100 feet along the terrace front, but the evidence of the presence of workable deposits is not yet convincing.

About one-fourth mile east of the Wills mine a number of pits were dug by Mr. Wills himself on the top of a flat-topped hill about 300 feet higher than the lower terrace where the mine is. This may represent an older valley floor. The rocks are deeply weathered and the pits are in residual clay and chert of the Shady dolomite which here dips northward away from the hill of Cambrian quartzite exposed in the anticline. The pits are about 6 feet deep and are scattered over the hill with a vertical range of 60 feet. A little good nodular ore was found in some of the pits and others were barren. The indications are not favorable for workable deposit.

Cornett Prospects.—One-half mile east-northeast of the Wills mine a prospect has been opened on the farm of Newton Cornett, of Mountain City. Several pits have been sunk to depths of about 12 feet on the upper south slope of a low ridge which is the northeastward extension of the Wills mine hill but about 300 feet higher, at the same general level as the Wills prospect. They disclose good nodular ore sporadically embedded in dull mottled residual clay of the Shady dolomite. The ore is mostly psilomelane, but includes a little manganite.

Three-fourths mile east-northeast of the Wills mine a prospect has been opened on the Mary Cornett farm. It is on the lower north slope of the same ridge on which the Newton Cornett prospect is, about 50 feet below the general level of the hill tops. It is in residual clay of the Shady dolomite and is opened by a narrow cut 40 feet long and 7 feet in maximum depth, showing practically throughout its extent good ore embedded in the clay. The ore is mostly psilomelane. About a ton of ore from the cut lay on the dump.

The developments on this and the Newton Cornett tracts were made by the Laurel Mining Company, of Mountain City. The indications are somewhat encouraging for a workable deposit.

Wright Prospect.—One-half mile east of the Mary Cornett prospect, across the small ravine, manganese ore has been recently reported to occur on the old Ward Iron Company property. It has been bought by W. C. Wright, of Mountain City, who is prospecting it, the results of which are said to be favorable.

Nelson King Prospect.—On the south side of the anticline adjacent to the Wills mine, especially on the farm of Nelson King two miles south-southwest of the mine, the surface of the cultivated fields carries float of nodular and lump ore among the chert fragments derived from the Shady dolomite. Some of the ore fragments are of good grade manganese ore, but considerable is manganiferous iron. Some of the road cuts in this vicinity also show dark manganiferous clay streaks with a little ore in the yellow residual clay. It will bear testing by inexpensive pits. but the surface indications are not very promising for a concentrated deposit.

Shouns Prospect.—The Shouns prospect is 2½ miles south of Mountain City and a mile south of Shouns Station, on the Virginia & Southwestern Railroad. It is on the south end of a low hill. part of a large tract owned by the Virginia Iron, Coal, & Coke Company, of Birmingham, Ala. It is undeveloped except for old shallow openings made for iron ore many years ago, one 60 feet above the valley bottom and others, including a shaft 20 feet deep, near the top of the hill 100 feet above. The shaft is in a massive, blocky, yellow glistening chert ledge, stained and slightly seamed by iron ore, which is believed to lie at the base of the Watauga shale in this region.

The manganese prospect consists of float ore scattered over the surface for about 100 feet up the front slope of the hill, below the chert talus. Although the ore is chiefly nodular and botryoidal psilo-

melane, it is somewhat impure and dull of luster. Some of it replaces chert breccia, which is derived from the weathering of the Watauga shale, but the nodular ore lies loose in the sandy soil on the slope. An unusually good example of the so-called grape ore, consisting of rounded nodules about the size of a large grape, firmly united together and forming a cluster 8 inches in length by 4 inches across, and tapering at one end, closely resembling a bunch of grapes, is illustrated three-fourths natural size in figure 2A of the first part of this paper (p. 158).

Little Doe Prospect (reported).—The Little Doe prospect is about three miles southwest of Mountain City, near the village of Little Doe. It is on the property of the Virginia Iron, Coal, & Coke Company and is undeveloped. Low grade manganese ore is reported to be abundant and appears to be worthy of thorough prospecting because of its convenient location and accessibility. It is apparently in Watauga shale, with relations similar to those at the Doe Valley mine to the southwest.

Doe Valley Mine.—The Doe Valley mine, also called Fritts mine, is seven miles southwest of Mountain City and about the same distance north of Doe Station on the Virginia & Southwestern Railroad. It is on the E. C. Fritts farm and is operated by the East Tennessee Mining Company, of Mountain City. Recent reports from the mine state that it is producing 60 tons of ore a month. A recent shipment ran 53% manganese, 4% iron, 6% silica. The best ore bed at present is in a cut 12 feet below what was the floor at the time of visit. It is 50 feet below the surface and is said to be the best body of ore yet encountered.

The deposit occurs in decomposed Watauga shale. The mine is described in detail as one of the types of manganese deposits in Part I of this paper (Res. of Tenn., Vol. VIII, No. 3, pp. 179-182).

Proffit Prospect (reported).—A prospect is reported on the Stacy Proffit property, 1½ miles northwest of Doe Station on the Virginia & Southwestern Railroad, and four miles north-northeast of Butler. It was undeveloped and was not visited by the writers. The Cambrian quartzite, which is brought to the surface in a sharp anticlinal fold at the southwest end of Doe Mountain and is possibly also faulted somewhat, is reported to be crushed and broken and re-cemented by manganese into a breccia, probably with some replacement of the quartzite by ore. The deposit is reported to have been recently prospected by H.

V. Maxwell, several trenches having been dug in the vicinity of the brecciated ledge, and may prove to be a milling proposition.

Wilson Hill Mine.—The Wilson Hill mine, also called Superior mine, is in the south-central part of the county, eight miles southwest of Mountain City and a mile south of Neva on the Virginia & Southwestern Railroad. It is owned and operated by the Superior Manganese Corporation, of Elizabethton. Since commencing work, early in 1918, the company by May 25, the time of visit, had done considerable prospecting and development work and had taken out more than 80 tons of manganese ore, but had made no shipments. The installation of mining and concentrating machinery and means of transporting the ore down the hillside were being planned, and were expected to be in operation early in August. In July it was reported that a pumping plant and a 40-ton double-log washer had been installed on Mill Creek, at the southeast foot of the hill, to which the ore is to be flumed from the mine. The water is to be raised about 600 feet to the mine.

The mine is on top of a high outlying knob at the northeast end of Dry Run Mountain, just west of the small settlement called Baker Gap. The ridge is about a mile long and rises steeply 600 to 800 feet above the adjacent valley bottoms. The southeastern slope is somewhat less steep than the northwestern and is covered with chert fragments and yellow clay apparently derived from Shady dolomite. Large masses of chert and chert breccia lie along the crest of the ridge and form ledges in places. Just below the northwest crest a quartzite, believed to be the Erwin, outcrops. It is brought up on a sharp anticlinal fold probably faulted on its northwest side. There is apparently also some faulting between the Shady dolomite and the quartzite along which line of movement the massive chert beds were developed by the replacement of the dolomite by silica from circulating waters, for massive chert is not normally present at the base of the Shady. Such chert beds have been observed at many fault contacts of the dolomite in the Appalachians. The manganese deposits occur chiefly in the clay and chert derived from the dolomite, on the upper southeastern slope of the ridge, between elevations of 2,600 and 2,800 feet. The development consisted of twelve or more openings spaced at intervals along the top of the ridge for about 2,000 feet from its northeast end, beyond which iron ores occur and were formerly mined near the southwest end

of the ridge. The openings comprise deep narrow pits or wells, trenches, and larger open cuts, some having a depth of 30 feet.

The ore is chiefly dull, somewhat impure, nodular psilomelane with a small amount of crystalline manganite enclosed in banded yellowish and dark waddy clay. Some of the waddy clay has also thin laminae of shiny ore and crystalline nuggets. In the chert ledges adjacent to the quartzite the ore is in a gangue of white crystalline secondary quartz, full of drusy cavities. Some of the ore on the southeast slope is brown iron with thin leaves of feathery manganite crystals.

The best showings are in the main opening at the north end of the hill. This trench is about 30 feet long by 10 feet wide and 10 feet deep, with a pit in the bottom about 13 feet deep, throughout which wash ore occurs in bands in the clay. The banding of yellow clay and dark manganiferous clay is about parallel to the foot wall of massive chert, which dips steeply to the southeast and probably represents original bedding. Most of the ore taken out came from this pit. About one-fourth of the ore consists of nodular lumps ranging up to 10 inches in diameter. The remainder is wash dirt. The nodules occur mostly in the yellowish clay. A short distance south of this opening is a cross trench 18 feet deep from which about ten tons of wad ore was obtained.

Back of these openings on the northwest crest of the ridge a shaft or narrow pit was being sunk in a ledge of siliceous rock carrying a little ore. It is largely vitreous, crystalline quartz enclosing numerous small, detached, oriented plumose, dendritic, manganese nodules which vary in size and number and may increase in quantity with depth, as claimed by the owners, so that it would become a workable milling ore, but at the time of visit a depth of 12 feet had not shown up such an ore. These plumose nodules are very interesting and seem to have been formed in the quartz mass when it was still gelatinous, for although they are isolated they have parallel orientation and the quartz was deposited around them with comb structure facing the small spaces between.

The next opening to the southwestward is a 25-foot trench 7 feet wide and 5 feet deep excavated in reddish-brown clay at the crest of the ridge, which is said to have yielded two tons of nodular lump ore and ten tons of wash ore. Several hundred feet beyond along the crest a wide shallow pit exposes massive chert covered at the surface with thin sheets or shell-like plates of ferruginous manganese.

Toward the southwest end of the tract the hill rises more rapidly and the soil and clay deepens. Several narrow round pits or wells have been sunk along the crest from 5 to 30 feet deep in yellowish to purplish clay containing chert fragments and a little lump and wash ore. Only in the deepest pit at the south end of the belt was any amount of ore seen, and the showing in these pits as a whole was not favorable.

On the mid-east slope of Wilson Hill several hundred feet southeast of the crest there are four pits closely spaced up and down the slope, and have a maximum depth of 18 feet. The deposit here consists chiefly of manganiferous iron ore in a liver-colored dense ferruginous chert ledge with a little psilomelane and thin plates of feathery brilliant manganite.

Another opening, a few hundred feet diagonally down the slope northward, is a shaft 22 feet deep, nearly all in slide material and showing thin layers or sheets of maganiferous iron ore and soft wad dipping southeastward approximately parallel with the surface. Still farther down the east slope, about 200 feet vertically below the highest pit on the crest of the hill, is a cut 9 feet wide and 3 feet deep at the face exposing a layer 8 feet wide composed largely of massive manganese ore which extends into the hillside beneath a covering of 1½ feet of surface soil and yellowish clay. A ton of lump manganese ore, two tons of wash ore, and a ton of manganiferous iron ore lie on the dump.

All these deposits are associated with the chert which is developed in the Shady dolomite apparently adjacent to a fault between it and the quartzite. The ore varies from nodular psilomelane to manganiferous iron ore, with a predominance of the latter, and although considerable tonnage can probably be developed, the better grade manganese ore will be only a small part of the whole.

BUTLER DISTRICT.

The Butler district includes the area around Butler, extending up the valleys northeastward between Doe Mountain, Dry Run Mountains, and Stony Mountain, southward up Elk Creek, and westward down Watauga River and up Cobb Creek. As Butler is near the western side of the county, several of the mines and prospects in the district are in Carter County and will be described under that heading.

Wagner Prospect.—The Wagner prospect is at the head of Little Dry Run, five miles northeast of Butler on the Virginia & Southwestern Railroad. It is on the D. A. Wagner property and the prospecting is being done by A. H. and J. J. McQueen, of Butler, under a lease. The deposits occur on a wash-covered terrace underlain by yellow residual clay of the Shady dolomite. A pit 12 feet deep shows wad and a little hard bluish psilomelane with rough exterior and partly stalactitic in structure, sporadically embedded in the terrace wash and in the underlying variegated dark and yellow residual clay. Larger lumps of float ore are found on the surface, but the heavy cover of wash conceals most of the showing of ore. Further prospecting is necessary to determine the presence of workable deposits, but the fact that it lies in the same syncline as the succesful Dry Run mine is favorable.

Dry Run Mine.—The Dry Run mine is 3½ miles northeast of Butler on the Virginia & Southwestern Railroad. It is owned and operated by A. H. McQueen, of Butler, but has recently been reported sold by him. In 1917 nearly 600 tons of ore were shipped. The better grade of ore, comprising the lump and larger size wash ore, averaged 44.5% manganese, 1.55% iron, and 1 to 10% silica; and the lower grade, comprising the medium and fine wash ore, averaged 38.5% manganese, 1.75% iron, and 21% silica. Shipments of corresponding grades of ore during 1918 ran: 43.5% manganese, 1.75% iron, 13.9% silica for the better ore, and 35.63% manganese, 1.75% iron, 25.83% silica for the lower grade. The ore is seen to be nearly free from iron, but rather high in silica. The washed ore has an unusually clean appearance.

The mine is on a low rounded hill at the foot of the northwest slope of Dry Run Mountain, 200 feet above the creek and about 2,350 feet in altitude. An 1,800-foot tram descends from the mine to a 22-foot double-log washer on Little Dry Run Creek where the ore is washed, the water being supplied from the creek by a gravity flume. The enclosing dirt is black and is easily washed away, yielding a clean product.

The deposit occurs in residual clay of the Shady dolomite which occupies the synclinal valley between the Dry Run Mountain and Little Dry Run Mountain anticlines. Although there are no rock outcrops nearby, the chert bed in the pit apparently dips southeastward so that it appears to lie on the northwestern limb of the syncline. The

chert forms the foot wall on the northwest side of the deposit. The deposits have been opened up for a length of 800 feet and the ore zone varies in width from 2 or 3 feet to a maximum of 15 feet.

There are three main openings. The southern one is a large pit 20 feet deep at the face. The ore lies in a bed, 4 to 6 feet thick, of dark manganiferous clay with psilomelane nodules, which strikes N 20° E and dips 65° SE. It is overlain by barren yellow clay containing streaks or layers of angular purple shale fragments in its upper part, and is underlain by dark-drab clay with some wad, which rests on the chert footwall. The purple shale streaks in the yellow clay are apparently old solution channel fillings.

The report that the ore bed runs about 75% ore seems to be justified by the exposures seen. The ore bed has been left unmined at several places where the overburden was heavier than elsewhere, but it is apparently of the same high grade and can be mined with profit, especially by steam shovel or drag-line scraper. The ore is mostly psilomelane, but contains also a little pyrolusite and manganite. The washed ore is almost all nodular or botryoidal. An unusual specimen comprising a cluster of radiating stalactitic rods is illustrated in Part I of this paper (Fig. 3B, p. 162).

The middle working is a tunnel 80 feet below the open pit, which runs westward into the hill 108 feet. It was not enterable at the time of visit, but is said to have passed through 30 feet of wash ore. It was not being used at the time of visit.

The northern pit is a deep hole filled with water, from which 16 carloads of ore had been shipped. It is reported to be 45 feet deep and the ore bed to be 14 feet wide. It was abandoned because of the increased overburden with depth, following down the dip of the ore bed to the southeast. At the time of visit the water was being drawn off so that the deposit could be again worked. A steam shovel or some other similar machinery was being considered to handle the large overburden economically and make accessible the deeper ores. Although a large quantity of ore has been removed from the mine, there is apparently still a considerable amount of ore present in depth and probably also in both directions along the strike. So far prospecting in these directions has not revealed the ore bed, but the area of bench land between the mine and the Wagner prospect to the north deserves careful prospecting.

Watauga River Mine.—The Watauga River mine is two miles southeast of Butler on the Virginia & Southwestern Railroad. It is operated by J. L. McQueen, of Butler, who has just installed a double-log washer in the gulch a few hundred feet below the mine on the wagon road near the river. The mine is on the upper northwest slope, about 30 feet below the crest, of a low ridge which is the southwestward continuation of Dry Run Mountain. The hilltop is 400 feet above the river, 2,400 feet in elevation, about the level of the old upper valley floor in this region. The deposit occurs in decomposed Watauga shale, which here dips 35° SE. A half ton of manganiferous iron ore lay at the mouth of the pit.

The mine consists of an open cut about 40 feet wide and an old shaft 30 feet deep, from the bottom of which a 50-foot drift runs southeastward into the hill. A trench was being driven lower on the hillside to open up the pit wider and deeper. The pit shows decomposed Watauga shale weathered to yellow sandy clay, with black waddy clay and some nodular ore filling a pocket 20 feet deep on the west side, with a vertical east wall of shale, resembling a solution pocket filling. The lower workings are said also to carry ore, but were not accessible at the time of visit and the mine was not running.

Cable Prospect.—The Cable prospect is two miles southeast of Butler on the Virginia & Southwestern Railroad. It is on the Cable property and the prospecting has been done by J. E. Reece, of Butler. It is on the lower southeast slope of the same ridge as the Watauga River mine, 2,200 feet in elevation and about 500 feet distant. The deposit occurs in decomposed Watauga shale, which dips 35° SE, and the deposit follows the bedding.

The openings consist of an old tunnel at the foot of the ridge, which is driven across the structure of the shale, and a shaft 60 feet higher than the tunnel. Although these old workings were in quest of iron ore, some manganese ore was encountered. The shaft, although caved, showed an ore zone of yellow clay containing scattered nodules of psilomelane and wad, which seemed to have a thickness of 8 feet, overlain by a layer of iron ore. The tunnel is in harder purple shale, with interbedded thin layers of residual, yellow, sandy clay containing scattered nodules of manganese. The amount of ore seems too small to mine.

Goss Mine.—The Goss mine is five miles southeast of Butler on the Virginia & Southwestern Railroad, and about two miles south of

Casper. It is at the southwest end of Stone Mountain, about 300 feet above Watauga River, from 2,300 to 2,360 feet in elevation. It is operated by the W. C. Goss Manganese Company, of Butler, J. E. Lineback, manager, which had recently shipped a carload of ore said to run 40% in manganese. The deposit occurs in residual clay and chert, presumably of the Shady dolomite, adjacent to hard purple Watauga shale and in the overlying wash. It is opened by two open cuts 20 to 30 feet deep, which cover a vertical range of more than 100 feet.

In the lowest or main opening, which is a narrow trench in the hillside 30 feet deep at the face, thinly laminated yellow clay is interbedded with chocolate buckfat clays which strike N 25° E and dip 80° SE. The ore occurs as small nodules and irregular bodies sparsely scattered through the yellow clay. It is chiefly psilomelane, but contains considerable silica in small crystals lining cavities in the ore. The ore is cleaned in a double-log washer at the foot of the slope to which it is carried by a steep flume. It is hauled to Casper over rough roads and thence to Butler, a total distance of over twelve miles. Apparently this siliceous ore is not mined and hauled this distance with profit.

Moody Prospect.—The Moody prospect is five miles southeast of Butler on the Virginia and Southwestern Railroad, just northeast of the Goss mine, on the north slope of the same ridge. It is on the W. R. Moody property and was opened by C. H. White, of Elizabethton. About three tons of ore were mined and were washed at the Goss plant and shipped with the ore from that mine. The mineral zone lies along the foot of the steeper northwest slope of Stone Mountain on a bench about 2,500 feet in elevation, in the residual clay of the Shady dolomite, which dips steeply away from the Erwin quartzite on the mountain, and may be somewhat faulted. It has been prospected at several places along this belt for a distance of one-fourth mile northeast of the Goss property.

The main openings are narrow deep trenches and pits up to 18 feet deep at the southwest end of the property adjacent to the Goss mine. Other shallow prospects have been sunk at the northeast end. They expose yellow clay and soil and many chert fragments characteristic of the Shady dolomite, and dolomite outcrops below the northeasternmost pit. Small irregular bodies of wad and scattered nodules of psilomelane occur in the clay, but in rather small quantities. Some of the psilomelane nodules are dense and heavy and contain some crys-

talline manganite. The prospect of finding a profitable deposit is not encouraging.

CARTER COUNTY.

Carter County, of which Elizabethton is the county seat, lies southwest of Johnson County and adjacent to the North Carolina State line. It is largely mountainous, only its western part being occupied by valleys. There are eighteen or more manganese mines and prospects in the county, about half of which have been productive and some of which are still producing. They occur mostly along a narrow belt on the northwest slope of Gap Creek and Iron mountains, which trends northeastward through the center of the county. Some lie on the south and southeast slopes of Holston Mountain in the northeastern part of the county.

BUTLER DISTRICT (CONTINUED).

Elk Mine.—The Elk mine is near Lineback, on Elk Creek, 2½ miles south of Butler on the Virginia & Southwestern Railroad. It is on the Hately and Lunsford properties and is operated by the McQueen Manganese Company, of Butler, of which A. H. and J. L. McQueen are the chief owners. It has produced about 60 tons of ore, with an average analysis of 38.07% manganese, 38% iron, and 19.27% silica. The last carload is said to have averaged 42.76% manganese.

The mine is on two small hills on opposite sides of a gulch west of Elk Creek. It is 130 feet above the creek where the log-washer is located, which is reached by an incline tram from the mine 1,600 feet in length. The older opening is on the northwest side of the gulch, more recent prospecting having been done on the southeast side. The deposits occur in decomposed Watauga shale, the general structure of which is monoclinal, the beds striking N 35° E and dipping on an average of 45° NW, but somewhat folded.

The main older opening is an open pit 20 feet wide and 40 feet long, on the northwest side of the gulch, from which an irregular incline descends along the ore zone to a depth of 40 feet. The shale is largely weathered to soft yellow sandy clay, but some less-weathered beds are still purple. An overburden of from 2 to 8 feet of earthy soil and purple shale fragments covers the residual clay. The ore is mostly psilomelane disseminated in one of the soft yellow sandy clay beds, probably a disintegrated calcareous sandstone. This ore-bearing bed is thin and the ore is not equally distributed in it, so that the

incline which follows it down is very intricately ramifying. Most of the ore mined came from a depth of more than 15 feet.

The opening on the southeast side of the gulch is a cross trench 15 feet deep, in the bottom of which is a narrow pit or shaft 60 feet deep, largely in purple shale, with a drift at its bottom in soft yellowish clay, in which most of the ore occurs. At the time of visit a tunnel was being driven to strike the ore zone below the present workings, which had caved, but this was later reported abandoned. About one-fourth of a ton of coarse cellular lump ore and twenty tons of wash ore lie on the dump, and more than forty tons have been shipped. The cavities of the lump ore are lined with crystalline manganite, and this ore is said to average more than 40% manganese. The cellular ore is made up of thin, platy walls which apparently formerly filled interstices of a brecciated rock, or more likely were deposits along joint and bedding planes of the original calcareous rock, which has also been more or less replaced by the ore, and the unreplaced portions of the rock have subsequently been dissolved out. The wash ore is mostly of nut to pea size.

The exposed ore seems to have been largely worked out, and it is not surprising that the mine was reported as closed down in July, 1918. However, as the ore in the decomposed layers of Watauga shale is so variable in its occurrence and at present cannot be predicted where it may be found, there may be other equally good deposits in the vicinity not yet discovered.

Dubault Prospect.—The Dubault prospect is on the Dubault farm, two miles southwest of Butler, and was opened by J. E. Reece, of Butler. It is on a low, flat-topped hill, 2,100 feet in elevation, on the north side of a deep narrow valley draining into Elk Creek. The deposit is in a narrow northeast trending belt of yellow residual clay and chert fragments probably derived from impure dolomite beds in the Watauga shale. Such dolomite beds in the formation are exposed on Elk Creek. It lies between hard, purple sandy shale on the west and whitish shale on the east. Only one hole was dug, an open cut 6 feet deep, which shows a few scattered nodules of psilomelane and wad in chocolate-colored clay. A little float ore is also at the surface, but the indications are not favorable.

Younce Prospect.—The Younce prospect is two miles southwest of Butler, one-fourth mile west of the Dubault prospect, on the farm of S. S. Younce. It was originally opened by the McQueen Manganese

Company, but is at present being developed by J. E. Reece, of Butler. About one-third ton of ore is on the dump. The openings are on a flat-topped hill, 2,180 feet in elevation, near the head of the narrow valley draining into Elk Creek. A deep, narrow, irregular pit follows down a thin bed of residual, sandy clay in Watauga shale, which carries the ore, to a depth of 50 feet. Several shallow trenches also are dug along the outcrop of this bed. The rocks strike N 80° E and dip 80° S.

The deposits consist of small nodules of psilomelane and streaks of wad in a 4-inch bed of yellow, sandy clay. The footwall is yellow, laminated clay in which is a thin bed of chert 12 inches below the ore zone. The hanging wall is banded yellow and drab clay with a little wad. The ore zone is so thin that even if it were much richer than is shown in the present pit it could not be profitably mined.

Cobb Creek Prospect.[1]—The Cobb Creek prospect is 2½ miles northwest of Butler, on a hill west of Highhealth, on Cobb Creek. It is on the farm of C. S. Morley, of Butler, and was opened by A. H. McQueen, of Butler. The deposit occurs in disintegrated Watauga shale on the top of a flat-topped hill or terrace, and seems to be in the same structural belt as the Doe Valley mine to the northeast. It is opened by a trench 40 feet by 50 feet and 3 feet deep. A ton of ore, mostly high grade, is on the dump. The prospect of a profitable deposit is regarded favorable.

STONY CREEK DISTRICT.

The Stony Creek district extends from Elizabethton sixteen miles northeastward to the county line, comprising Stony Creek Valley, about five miles in width, between Holston Mountain on the northwest and Iron Mountain on the southeast.

Blevins Mine.—The Blevins mine is located in the northeast corner of the county, 1½ miles up Blevins Hollow northwest from Colesville on the Stony Creek branch of the Virginia & Southwestern Railroad. The property is owned by Mrs. Isaac Blevins, who lives on the place. Captain Robinson, of Elizabethton, opened up the mine several years ago and shipped a carload of ore in 1917. His option has expired and has not been renewed.

[1]From notes by A. H. McQueen and Nelson Dale.

The mine is on the top of a small terraced spur of Holston Mountain, at an elevation of approximately 2,500 feet, part of the old valley-floor bench. The deposits occur in surface wash of light-brown to chocolate-colored clay 8 to 10 feet thick and in underlying yellow residual clay derived from Shady dolomite, which overlies greenish sandy shales of the basal part of the Shady.

As exposed by a dozen or more openings scattered over the upper part of the hill the deposit has a horizontal extent of more than 500 feet. These openings are mainly round pits or wells 8 to 10 feet deep, and on the north side of the hilltop a larger open cut extends to a maximum depth of 18 feet. The ore in most of the pits is nodular psilomelane with dull luster, sporadically embedded in the clay chiefly at a depth of 8 to 10 feet, near the base of the surface wash. In the large north pit there are also two or three layers each 1 foot thick of soft black wad and pyrolusite interbedded in the underlying light-yellow to chocolate-colored residual clay dipping low toward the north. Lumps of dull, earthly psilomelane on the dump are somewhat impure and apparently will not run over 35° manganese.

Hatcher Prospect.—The Hatcher prospect is in the northeastern part of the county one mile east of Sadie Station on the Stony Creek branch of the Virginia & Southwestern Railroad. It is on the Hatcher land and was opened fifteen years ago by Col. J. N. Adams, of Charleston, Tenn. H. E. Graves, of Bristol, has been recently prospecting it.

It is on a terraced spur on the lower northwest slope of Iron Mountain, at an elevation of approximately 2,350 feet. It is about 150 feet above the opening of the Hatcher sulphur mine, where iron pyrites has been mined in the upper layers of the Erwin quartzite.

The deposit occurs in residual clay of the Shady dolomite just above the Erwin quartzite, which dips 40° NW away from the mountains. A pit 4 feet deep on the top of the terrace is in dark-reddish soil characteristic of the Shady dolomite ore zone, in which are a few nodules of psilomelane and iron ore. A few fragments of float ore are also scattered over an acre of the upper surface of the ridge. The amount of ore is apparently very small.

Grindstaff Prospect.—The Grindstaff prospect is located southwest just across the small hollow from the Hatcher prospect, on a similar terraced spur. It is owned by G. L. Grindstaff, by whom it has been prospected by auger borings to a depth of 4 feet. The geologic and surface relations are similar to those at the Hatcher prospect.

Other Prospects in Stony Creek Valley.—There are several old iron mines on the northwest slope of Iron Mountain, all of which are now closed, but their scars on the mountain slope are plainly visible from the valley bottom. Some of these are on benches along the slope like those at the Hatcher and Grindstaff prospects, and the reported occurrence of manganese ore float at such places is to be expected. None had been opened by pits, however, so far as known. Prospects on the southeast slope of Holston Mountain were also reported, but no openings were to be seen. Excellent float iron ore, locally called "cannon" ore because of its denseness, hardness, and weight, occurs on this mountain slope and is especially plentiful west of Winner Station, chiefly on the Government Forest Reserve.

Blue Springs Mine.—The Blue Springs mine is in the north-central part of the county one-half mile south of Blue Springs and four miles east of Hunter Station on the Virginia & Southwestern Railroad. It is owned by the Carrigan heirs and is operated by Walker & McKenna, of Elizabethton. It is credited with a production of 500 tons of manganese ore, of which eleven carloads were shipped many years ago and 75 tons more recently by Col. J. N. Adams, of Charleston, Tenn., who had a log-washer just below the mine. A carload was also mined and shipped about one year ago by H. V. Maxwell for H. E. Graves, of Bristol.

The mine is on a terraced spur on the lower northwest slope of Iron Mountain. This bench is at an elevation of 2,000 to 2,200 feet, which corresponds with the tops of many neighboring spurs and ridges that are regarded as remnants of the old valley floor.

The old mine workings were deep open cuts on the hillside, which are now largely caved in. They still show a considerable amount of good wash ore on their dumps, particularly the higher ones, which are on the Virginia Iron, Coal, & Coke Company's land, which is being absorbed into the Government Forest Reserve and has not been recently worked. The recent workings comprise several trenches 8 to 10 feet deep and short tunnels. Most of them expose dark clays at the surface overlying horizontally banded clays. The latter are apparently residual clay derived from beds in the lower part of the Shady dolomite. The ore lies in the chocolate-colored sandy clay, which is generally not over 5 feet deep, the yellow clay beneath being mostly barren. In the upper tunnel the yellow clay is locally overlain by jointed dry white clay, which is stained by iron along the joints.

The ore is chiefly hard psilomelane in nodules ranging up to 8 inches in size and in larger irregular masses. There is also present a considerable amount of soft black ore, in part pyrolusite, which will be largely lost if passed through the washer. The concentration of the ore in the wash dirt was not determined. The areal extent of the deposit is large and considerable minable ore is believed to be still in the ground.

Keesburg Prospect.—The Keesburg prospect is in the western part of the county, three miles north of Elizabethton and a mile east of Keesburg on the Virginia & Southwestern Railroad. It is on the property of the Southern Minerals Corporation, of Boston, Mass., adjacent to their brauxite mine, and has recently been opened by them. It is on the terraced spur at the southwest end of Holston Mountain, known as Red Bird Hill, at an elevation of 2,200 to 2,300 feet, and is a little higher than most of the hilltops in the vicinity which seem to be a remnant of the old valley floor.

The deposit occurs in residual dark-red clay of the basal part of the Shady dolomite and in the adjacent Erwin quartzite. The quartzite strikes N 30° W and dips 40° SW, and its outcrop at the top of the hill back of the terrace is brecciated and cemented by manganese ore. Although this ledge has been prospected, it is too siliceous to be profitably mined. The deposits on the terrace below the quartzite hill are opened at several places. On the front-edge of the terrace manganese ore float in scattered over the surface with chert fragments, and is found in the upper surficial layers of reddish and pale-lavender clay in the bauxite pits and cuts. The ore is chiefly nodular and stalactitic psilomelane, some of which is coated with black shiny iron ore and contains a little crystalline manganite. On the northwest slope of the hill a few shallow cuts expose a little ore in similar dark-red clay.

The amount of ore in all the pits is too small to be profitably mined except possibly as a by-product to be saved in mining the bauxite.

HAMPTON DISTRICT.

The most important district as a manganese producer in the county is the Hampton district, which comprises the region around Hampton. It includes not only the valley between the Stone Mountain-Pond Mountain group on the southeast and Gap Creek-Iron Mountain group

on the northwest, in which Hampton is located, but also the edge of the great valley at the northwest foot of the latter ridges.

Cardens Bluff Mine.—The Cardens Bluff mine is located in the central part of the county about four miles northeast of Hampton and one-half mile southwest of Cardens Bluff, the nearest railroad station on the Virginia & Southwestern Railroad. It is owned and operated by A. D. Reynolds, of Bristol, and L. L. McQueen, of Butler. In 1917 182 tons of ore were shipped, which averaged 36.56% manganese, 9.05% iron, and 22.51% silica. Several carloads were in the bins at the washer at the time of visit, and it has since been reported that 400 tons were shipped during the first half of 1918, having an average analysis of 30% manganese, 10% iron, and 25% silica.

The mine is on the upper west slope of a prominent terrace at the northwest foot of Pond Mountain, at an elevation of 2,130 to 2,200 feet, about 300 feet above Watauga River. The terrace is a remnant of the old valley floor. The deposits occur in yellowish to reddish residual clay and chert fragments of the Shady dolomite. Just below the mine the unweathered dolomite outcrops dipping 85° NNW. The overburden is about 3 feet of soil and clay.

A large trench about 80 feet across and extending up the hill 200 feet, opens up the face in three benches each 6 to 12 feet deep. The ore came chiefly from a zone 1 to 6 feet below the surface, which was well exposed in the face of one of the benches for a width of 20 feet. In the deepest part of the working ore-bearing clay continues to the bottom of the cut. The chert in the clay is partly replaced by ore.

The ore is conveyed from the mine by a short hand cable incline to a loading platform and thence by a gravity-horse tram to the log-washer, which is located about one-fourth mile to the west on a small creek.

The ore is chiefly wad, psilomelane, and pyrolusite, much of it being soft and sooty, but some is crystalline pyrolusite. The washed ore is dirty looking, resembling earthy, chocolate-colored lumps of clay. The analyses show it to contain much silica, or insoluble matter, which is probably in part aluminum. The ore is so high in silica and low in manganese that it is not surprising to learn that the mine has recently closed down.

Teaster and Ray Prospect.—Two miles southwest of the Cardens Bluff mine prospecting has been done along the Hampton road by M. G. Teaster and T. J. Ray, of Elk Park, N. C. The property is on a

low hill south of the road at the head of the small branch of Doe River. A pit 4 feet deep exposes lumps of psilomelane in earthy clay containing sandstone fragments and the deposit is probably in wash lying on the old valley floor. On the spur of Pond Mountain, southeast of the prospect, about 500 feet above the road, manganese is reported to have been found below the quartzite ledges, from which the wash deposit was probably derived.

Cedar Hill Mine.—The Cedar Hill mine is one mile south of Hampton and one-third mile from the East Tennessee & Western North Carolina Railroad. It is owned by the Stiles heirs, of California. It was worked for iron twenty to thirty years ago, and was only recently leased and opened for manganese by H. V. Maxwell, of Elizabethton. At the time of visit (May 16) he had just begun operating with a force of ten men, and had shipped a carload of ore washed in a single 20-foot log-washer. It was planned to install a double-log washer and to equip the incline with larger cars to increase the production. The carload shipments reported to date analyzed from 46.51 to 48% manganese, 8 to 8.45% iron, 4.5 to 5.65% silica, 2.11 to 4.92% alumina.

The mine is located on the top of a terraced spur at the northwest end of White Rock Mountain at an elevation of 2,150 feet, or about 350 feet above the adjoining lowland of Doe River where the washer is in operation. The water is flumed to the washer from a low dam in the river. The ore is brought to the washer by a cable incline down the slope 1,400 feet long and a gravity-mule tram on the valley bottom 900 feet long.

Small pits have been opened on the top of the terrace adjacent to old iron pits in one of which a ledge of good brown-iron ore is still exposed. Clay containing yellow chert with drusy cavities, probably derived from Shady dolomite, lies on the slope below the ore zone and Erwin quartzite outcrops on the mountain slope above. Yellow and white clay with a little manganese ore occur in the pits.

The main opening is a large open cut on the north crest of the hill running southeast into the hill. It has a face about 30 feet high, with a tunnel at its end, all more or less slumped. The new opening on one side, 20 feet wide, has a face 15 feet high which is almost all dark manganiferous clay and soil interbedded with some yellow clay. The yellow clay carries nodules of psilomelane, and the dark soil also contains some hard ore, but has large pockets of soft ore, graphitic in character, nodular in form, and with radiate

needle structure. Most of the soft ore crushes to powder on handling and would be lost in the washer, so it it is bagged at the pit and shipped unwashed. The nodular psilomelane is mostly small, resulting in nut ore, pea ore, and screenings, and the analyses would probably run much lower in manganese if the higher grade soft ore were not saved and mixed with it. A 5-foot horse of barren buckfat yellow clay is exposed in the midst of the cut. This appears to be the unmoved residual clay of the Shady dolomite, whereas the ore-bearing clay is apparently residual clay that has slumped and settled into solution depressions and pockets on the old land surface or valley floor and has been impregnated with ore.

The ore shipped is of good grade and the quantity appears ample to justify the proposed enlargement of the plant. A considerable area of prospective ground is still available on the hilltop. It was stated by Mr. Maxwell that float ore has been found all along the northwest foot of the mountain from his mine to the Cardens Bluff mine, and as the geologic and surface relations are favorable for ore accumulation in this belt, other good deposits may be expected on the benches of the same elevation as these mines along the foot of the mountain.

Valley Forge Mine.[1]—The Valley Forge mine, formerly known as the Toncray mine, is in the central part of the county, three-fourths mile east of Valley Forge on the East Tennessee & Western North Carolina Railroad. It is owned and operated by the Valley Forge Mining Company, of Bristol, Va., composed chiefly of H. W. and A. D. Reynolds. It is reported to have shipped in 1917 about 800 tons of ore, of which 50 tons averaged 43% manganese, 3% iron, and 6% silica. At the time of visit the company expected to ship 500 tons in the first half of 1918. Average analyses of carload shipments of this ore were later reported to have run 42 to 46% manganese, 4.8 to 8% iron, 9.2 to 12% silica.

The mine is located on the northwest slope of the southwest end of Iron Mountain, at an elevation of about 2,240 feet, or about 500 feet above Doe River, which is about three-fourths mile distant to the south. It is in the upper part of a short terraced ridge projecting to the northwest, which is a remnant of an eroded old high valley floor. Similar terraced spurs at about the same level to the northeast are

[1]Description by F. C. Schrader.

favorable places to prospect. Old caved pits and dumps corroborate the report that immediately adjacent portions of the ridge were mined for iron many years ago.

The deposit occurs in residual clay of the Shady dolomite near its contact with the underlying Erwin quartzite on the southeast. The structure is monoclinal, the dip of the rocks being about 60 degrees to the north-northwest. The clay is mostly dark reddish or earthy and chocolate-colored. In this clay the ore is sporadically embedded in the form of hard nodules and botryoidal aggregates consisting chiefly of psilomelane.

The deposits are mostly contained in a mineralized zone about 60 feet in width, which trends 400 feet or more east-northeast, seemingly through the trunk of the spur on both sides of which they are exposed. They have a known vertical range of about 160 feet. On the northeast slope of the spur developments begin at an elevation of 2,100 feet in yellow clay, but no ore was found below an elevation of 2,175 feet, from which point the developments and deposits extend interruptedly up the 35° slope to where the tram crosses the ridge at 2,280 feet in elevation. Surface indications of ore continue up the spur to the top at 2,340 feet elevation.

Several tunnels on the northeast slope of the spur not enterable at the time of visit form a considerable part of the development. The lowest tunnel is 150 feet in length. It is driven southwestward into the hill in yellow clay and encountered no ore. The intermediate tunnel, 100 feet in length, runs south into the hill and is said to have found a trace of gravelly manganese ore in red clay in the face. The upper tunnel starts near the collar of the shaft, near the lower limit of the main deposit, and runs westward into the hill, and is said to be 120 feet long with ore present all the way. However, the ore is said to be best developed at depths between 10 and 15 feet, and about all the ore which has thus far been mined seems to have come from depths not exceeding 30 feet. The seat of present operations is an open pit on the northeast side of the spur at about 100 feet below the crest in the vicinity of the upper tunnel and a little higher than the shaft. The shaft passes through 5 feet of dark-reddish ore-bearing clay, then 18 feet of barren yellow buckfat clay, below which ore is again encountered. The ground now being worked in the pit seems to be the same as that in the upper part of the shaft.

The ore is mostly hard psilomelane. It occurs in rough nodules and in slabs or fragments of aggregate botryoidal and mammillated forms. There is present, however, a moderate amount of soft crystalline and sooty pyrolusite and wad. Nodules 2½ inches in diameter of dark-brown wad seemingly of good grade were noted.

The equipment consists chiefly of a four-log washer and pump, with about 4,000 feet of pipe line, one-half mile of tram, cast iron flume, gasoline engine, and several buildings. The washer, just installed, is located on the southwest slope of the spur at a point about midway between the mine and the river, whence a gravity tram extends southward to the railroad at the river, where the pump is stationed which forces water to the washer and mine. From the mine the ore is raised by gasoline engine up a short incline tram to the crest of the ridge, 80 feet above, from which point it is conveyed through a cast-iron flume to the washer. When fully equipped, the company expects to produce about forty tons of ore a day.

Jenkins and Hyder Prospects (reported).—The Jenkins prospect is two miles southwest of Valley Forge on the East Tennessee & Western North Carolina Railroad. It is owned by the Abe Jenkins heirs and was opened by J. N. Koch, W. P. Davis, B. Aubrey Smith, and Henry Hudson, of Knoxville, in 1917. A carload of ore was mined and shipped in 1917, and the prospect was then abandoned as not profitable. A test analysis of the ore was reported to run 36.20% manganese, 4.78% iron, 17.71% silica.

The prospect is on a terraced spur about 2,200 feet in elevation on the northwest slope of Gap Creek Mountain, near its northeastern end. It is in residual clay of the Shady dolomite, and the ore was said to consist chiefly of nodular psilomelane. Float ore is reported on adjacent terraced spurs at this general level on the northwest slope of the mountain, and deposits probably extend along its whole length.

The Hyder prospects are about three miles southwest of Valley Forge, one mile beyond the Jenkins prospect. One is on Eliza Jane Hyder's farm and another is southwestward on Oscar Hyder's farm, both on terraced spurs of Gap Creek Mountain, about 2,200 feet in elevation. Another pit still further southwest near Gap Creek is on Marion Hyder's farm on a similar bench 2,150 feet in elevation. These are all small surface openings in dark manganiferous clay on yellow clay residual from Shady dolomite and show some psilomelane. They

were opened by J. N. Koch and associates, of Knoxville, and were abandoned without enough work being done to determine their worth.

Winter Mine.—The Winter mine, also known as the Taylor mine, is seven miles southeast of Johnson City and four miles south of Watauga Point on the Tennessee & Western North Carolina Railroad. The property is owned by the Taylor heirs and was opened by the Maxwell Manganese Mining Company, of Elizabethton, which mined and shipped a carload of ore, including some from the nearby Patton mine, said to have analyzed 45.9% manganese. About forty tons of good wash ore, mostly nut and pea size, lie on the dump at the mine and twenty tons of washed ore are at the washer. The mine has recently been leased by the old company to the Max Mining Company, Braemar, Tenn., of which H. V. Maxwell, of Elizabethton, is the active representative, and they are now installing a double-log washer which is expected to be in operation about October 1. The Patton mine, also on the Taylor property, is to be included under the same operation.

The mine is on a terraced spur 2,200 feet in elevation on the northwest slope of Gap Creek Mountain, about two miles southwest of the Hyder prospects. The trough in which the ore was washed is on a small headwater branch of Powder Creek a short distance below the mine, to which the ore was hauled by wagon.

The deposit occurs in banded residual clay containing round cherts, derived from lower beds of Shady dolomite. Two layers of wad and ore in dark clay, each 1½ feet thick, alternate with banded yellow to red clay, in part streaked with manganese films and stains along the foliation planes. These beds strike N 60° E and dip 80° SE. Purple shale of the Watauga crops on the lower slope of the spur with the same dip, which indicates a steeply overturned monoclinal structure. Erwin quartzite fragments cover the surface of the steep slope above the mine.

The ore consists of psilomelane and manganite, much of which is pitted and lined with crystals. More than 50 per cent of the ore is apparently crystalline manganite. The ore occurs in nodules and irregular lumps, some several hundred pounds in weight having been reported. Its pitted or cellular condition is apparently due to rock fragments which have been dissolved out of the ore. Some ore still firmly incloses chert fragments.

The deposits are opened chiefly by a 40-foot cut, 16 feet deep at the face, and by an incline shaft 20 feet or more in depth. The cut is in

clay laminated by dark manganese stain and crossed by a zone 4 feet wide, which contains nodules and much soft ore in a narrow band. The shaft is 8 feet to the left of the cut and follows the ore zone down the steep dip.

Small shallow pits extend 50 feet or more northeast of the mine toward the old workings near the crest of the spur and deposits are probably distributed over an area of several acres adjacent to the mine. Float ore is reported to have been traced northeastward along the slope of the mountain for more than a mile. Southwest, across the small ravine, other small pits on the steep slope of the next interstream terrace reveal some good nodular ore in characteristic dark-red soil which indicates that this terrace is probably also underlain by similar deposits. Another opening on the lower northwest part of the same spur is in purple Watauga shale but shows only iron and a little manganese ore.

Patton Mine.—The Patton mine is six miles southeast of Johnson City and lies one-half mile southwest of the Winter mine, on the same mountain slope. The property is owned by the Taylor heirs. The deposit was first opened in a small way in 1908 by S. Joberg, who shipped some ore. In 1917 it was operated by the Maxwell Manganese Mining Company, of Elizabethton, which produced thirty tons of ore averaging 42.27% manganese, 6.16% iron, and 13.48% silica. The mine is now leased to the Max Mining Company, to be operated in conjunction with the Winter mine.

The mine is opened by a deep pit at the base of the steep north bank of a narrow gulch containing the headwaters of Powder Branch. The pit extends into the bottom of the gulch, whose stream was diverted around it, but it is now filled with water. The 20-foot high face of the cut is yellow clay streaked with layers of wad and cut by red-clay seams. The clay is residual from the Shady dolomite and dips 55° S, probably overturned in a steep monocline. The ore-bearing layer of dark waddy clay has a width of about 20 feet and carries good ore masses nearly to the surface.

The ore is nodular psilomelane with considerable crystalline manganite. Several masses 2 feet in diameter of good ore were noted on the dump. The high grade of the ore, the favorable showing in the bank, and the large amount of ore said to have been taken from the pocket are favorable indications that the bank and terrace above contain a deposit of workable ore.

Treadway Prospect.—The Treadway prospect is six miles southeast of Johnson City and 1½ miles southwest of the Patton mine, on the east side of Dry Creek gap. It is in a small ravine on the lower northwest slope of Gap Creek Mountain along the same belt as the Patton and Winter mines, at an elevation of about 2,100 feet. The property is owned by George Treadway, of Okolona, and was being prospected by W. H. Kemler, of Johnson City.

The deposit is in dark residual clay of the Shady dolomite, apparently close to the contact with the Erwin quartzite. The structure is believed to be monoclinal, the Watauga shale standing vertical and striking parallel to the mountain on the slope below. A pit 12 feet deep at the face is driven into the north side of the ravine, exposing dark dry powdery clay and sandy wash containing a few small nodules of hard psilomelane and irregular bodies of wad. Some larger pieces of good float ore occur below the pit. Samples of this ore are reported to have yielded 40% manganese. A few hundred yards east of the opening a little manganese float and iron ore cementing quartzite breccia extends up the slope of the low-terraced ridge. The showing, however, is not promising.

Hodge Prospect.—The Hodge prospect is six miles southeast of Johnson City, on the southwest side of Dry Creek gap, one-half mile from the Treadway prospect. It is on a low terrace on the northeast end of Little Mountain. The property is ownd by Frances Hodge, of Okolona, and was being prospected by W. H. Kemler, of Johnson City.

The deposit is in residual clay of the Shady dolomite and in the overlying sandy wash. A small offset of the mountain front at the gap is apparently due to a local syncline in the underlying quartzite and the Shady dolomite at the prospect apparently lies in this syncline. At the creek dolomite outcrops in vertical beds, but on the terrace it is deeply decomposed to clay. Several pits about 6 feet deep show only siliceous manganese ore in reddish clay. Some large masses of good psilomelane ore were plowed up in the fields below, which are reported to have analyzed 40% manganese.

Although the showing in the pits is poor, the high grade float ore on the slope and the apparent synclinal structure are favorable for a deposit of workable size, and further prospecting on the top of the terrace above the present pits is advised.

UNICOI DISTRICT.

This district is chiefly in Unicoi County and will be described under that heading. One mine in this district is in Carter County.

T. J. Brummett Mine.—The T. J. Brummett mine is at the head of Dry Creek, close to the county line in the southwestern part of the county, four miles northeast of Unicoi on the Carolina, Clinchfield & Ohio Railroad. It is on the farm of T. J. Brummett, of Unicoi, and is operated by the Southern Manganese Corporation, of Birmingham, Ala. Some prospecting, presumably for iron, was done here in early days, but no further work was done until the spring of 1918, when the deposits were opened for manganese by W. H. Kemler, of Johnson City. By the middle of May an open cut 20 feet deep and several smaller pits had been dug and ten tons of ore were on the dump. The ore was said to run about 52% in manganese.

The mine is on the north side of a small hill on the divide between Scioto and Dry creeks, connecting little Mountain and Stone Mountain. Little Mountain is the southwestward continuation of Gap Creek Mountain. The mine is on a bench approximately 2,400 feet in elevation, which is also the elevation of the stream divide and of other old, valley-floor remnants. The small hill at the divide rises 150 feet higher.

The deposit occurs in residual clay of the Shady dolomite close to the Erwin quartzite. The Scioto-Dry Creek valley is in general a syncline between quartzite mountains, faulted on the northwest side and inclosing Watauga shale in the center. Erwin quartzite is brought up on a local anticline on the small knob back of the mine and the narrow syncline to the southeast of this apparently plunges southwestward down Scioto Creek and merges with the larger syncline. It was not traced northeastward down Dry Creek. The Shady dolomite outcrops on the northwest side of the hill adjacent to the quartzite, striking N 45° E and dipping 75° NW. The mine is in the clay residual from this dolomite on the north slope. Watauga shale outcrops at the west foot of the hill. The deposit thus occurs on a steep monocline at the contact of the Erwin quartzite and Shady dolomite.

The ore is chiefly psilomelane and occurs as nodules, lumps, and irregular bodies embedded in dark-red clay. Some lumps 2½ feet in diameter were seen, but most of the ore is smaller than 3 inches across. Some of the ore has a botryoidal and mammillated surface and much

of it is more or less cellular. Some is composed of thin, wavy, concentric layers. On the east side of the main pit the ore is sandy and apparently replaces the Erwin quartzite at the contact. At the west side next to a bed of iron ore the manganese ore is speckled with small flakes of iridescent or peacock-colored hematite.

The main cut is 40 feet in length, 15 feet in width, and 15 feet in depth at the face. It runs southwesterly into the hillside apparently at the Erwin-Shady contact. Greenish and red sand inclosing white quartzite masses veined with manganese on the east side apparently represent the quartzite ledges on top of the hill. Between this and the dark-red soil of the Shady dolomite is a vertical layer of red hematite iron ore and black clay with manganese ore, and there is another vertical layer of manganese and iron ore on the west side of the pit. The red clay between contains good nodular ore throughout, and has yielded most of the ore thus far mined. Its lower limit has not yet been reached.

Fifteen feet back of the main cut is an old shaft 10 feet deep which exposes some good ore beneath an iron capping. Forty feet farther southwest a trench 80 feet long and 15 feet deep in red clay shows considerable manganiferous-iron ore from the surface down, with a small amount of manganese ore in the lower part. Forty feet to the westward a 7-foot pit in red clay shows ore in its lower part.

About 300 feet southwestward from the main cut, and 15 feet higher up the slope, a 12-foot cut with a face 5 feet high in dark earthy-looking clay shows good psilomelane, pyrolusite, wad, and manganite from the surface to the bottom, which has yielded considerable wash ore on the dump. The deposit has thus been exposed by prospecting for a length of about 500 feet and a width of 150 feet, but it is not all minable ore, and its depth has not been determined, but is probably not great.

UNICOI COUNTY.

Unicoi County adjoins Carter County on the southwest and is a narrow mountainous county adjacent to the border of the State. The State line follows the crest of Iron, Unaka, and Bald mountains, and the western boundary of the county follows the crest of Buffalo Mountain and other mountains to the southwest. The long valley between these two ranges of mountains is chiefly tributary to Nolichucky River, which cuts the county in two, transversely, at its narrowest part. The

two active mines in the county, Susan Brummett and Britt, together with the T. J. Brummett mine in Carter County, are in the Unicoi district. A few prospects in the northwestern part of the county are in the Bumpass Cove district.

UNICOI DISTRICT.

The Unicoi district embraces the area around the town of Unicoi, and includes the valley of North Indian Creek and of its several tributaries. At present mining is restricted to the Scioto Creek valley.

Susan Brummett Mine.—The Susan Brummett mine is in Scioto Creek valley in the northeastern part of the county three miles northeast of Unicoi on the Carolina, Clinchfield, & Ohio Railroad. It is on the farm of Susan Brummett, of Unicoi, and is being operated by the Southern Manganese Corporation, of Birmingham, Ala. It produced some ore in the early eighties, since which time it lay idle until it was recently reopened by W. H. Kemler, of Johnson City. At the time of visit, May 3, 1918, a double-log washer was being installed and storage bins were being built to supply the washer for night work so as to run day and night. The scarcity of water in the local branch prevented the operation of the plant during the summer and it was proposed to run a pipe line from North Indian Creek, near Unicoi, to the mine.

The mine is on a low terrace about 50 feet high, on the east side of Scioto Creek, at the northwest foot of Stone Mountain. It is in dark-red clay, which lies between Watauga shale at Scioto Creek and Erwin quartzite on Stone Mountain, and is evidently residual from Shady dolomite on a northwestward dipping monocline, although nowhere does the dolomite outcrop. The surface below the mine is strewn with chert from the Shady. Surface indications of this ore zone are reported to have been traced from the vicinity of Unicoi five or six miles northeast along the southeast side of Scioto Valley. Part of this land is now included in the U. S. Forest Reserve and mining privileges have not yet been obtained.

The deposit is opened mainly by an open cut 50 feet long northward into the hill from a small ravine. It is 10 to 20 feet wide and 20 feet deep at the face. The ore is apparently deposited chiefly at the bottom of the surface wash, but some is in the underlying dark-red residual clay. Most of it is psilomelane with a little manganite and pyrolusite. The ore is rather low grade, much of that from the sur-

face wash enclosing sand grains, and it is reported to average only 38% manganese. The company planned to wash all the dirt handled, as it was believed to run one-third ore.

Britt Mine.—The Britt mine is also in Scioto Creek valley in the northeastern part of the county, one mile southwest of the Susan Brummett mine and two miles northeast of Unicoi on the Carolina, Clinchfield, & Ohio Railroad. It is on the farm of J. L. Britt, of Unicoi, and is being operated by the Southern Manganese Corporation, of Birmingham, Ala. It was first opened and a carload of ore shipped in 1898 by Colonel Kirk, and was later reopened by W. H. Kemler, of Johnson City. At the time of visit a double-log washer was being installed.

The mine is on a low-terraced hill on the east side of Scioto Creek, about 50 feet above the creek, at the northwest base of Stone Mountain. The deposit is in surface wash, which overlies brownish variegated clay of the Shady dolomite near its contact with the underlying Erwin quartzite on the southeast, the structure being monoclinal. No rock outcrops were observed and the dip was therefore not determined.

The deposits are opened by a series of about ten narrow cuts running northwest into the hill from a small side ravine and spaced over a distance of 300 feet. The longest cut is 60 feet, and the deepest 22 feet at the face. Other prospect pits were reported several hundred yards north of the mine, but these were not visited. Little ore was seen in the walls of most of the pits. The largest and deepest pit, which is at the southeast and apparently close to the sandstone contact, shows two layers of dark wad carrying hard manganese ore interbedded with dark slickened clay enclosing sandstone fragments which extend to the bottom of the cut.

The ore is chiefly nodular psilomelane, much of which incloses grains of quartz and some is coated with red oxide of iron. Small fragments of crystalline manganite and soft black pyrolusite and wad are also present. Considerable iron ore is also on the dump. The ore had been washed in a trough by a strong current of water from a flume and several tons of washed screenings were on the dump. Also about 80 tons of small gravelly wash dirt and a few tons of coarser red-coated ferruginous manganese ore were in piles. The ore is thus seen to be of low grade, high in iron and silica, and it is doubtful if it can be profitably worked unless all the dirt handled is wash ore.

Other Prospects.—Several other prospects or surface showings of ore were reported in the vicinity of Unicoi on Government Forest Reserve land, but at the time of visit were not being actively prospected. Old iron pits occur on the slopes of the surrounding hills and manganese indications were seen in the road cut at the south end of Little Mountain. Manganese float was reported on the bench 2,100 to 2,200 feet in elevation all along the northwest foot of Little Mountain. As the geologic and surface conditions are favorable for the occurrence of manganese ore, and as it is in the same zone as the good deposits at the Winter and Patton mines, this bench from Unicoi northeast to Dry Creek Gap is a desirable place to search for workable ore deposits.

BUMPASS COVE DISTRICT.

Bumpass Cove lies southwest of Embreeville and is partly in Unicoi County and partly in Washington County. As most of the opened manganese prospects are in Unicoi County, they will be described here under the head of Bumpass Cove district. The cove is almost surrounded by mountains. In the past it has been the source of much iron, lead, and zinc ores, and now manganese is being prospected there.

Embreeville Prospect.—The Embreeville prospect is at the northwestern border of the county near the head of Bumpass Cove, three miles southwest of Embreeville. It is on the Embree Iron Company's railroad, which connects with the Embreeville branch of the Southern Railroad from Johnson City. The deposit extends northeastward across the county line into Washington County.

The land is owned by the Embree Iron Company, of Embreeville and Chicago. Iron ore was mined by the company for many years, but more recently zinc and lead have been chiefly mined. Manganese has been only recently discovered and prospecting by the company began in 1918. The prospects are on a terrace on the northwest side of the cove at about 2,070 feet elevation, which is a remnant of an old valley floor.

The deposit lies in dark-reddish and yellowish clay residual from the Shady dolomite close to the contact with the underlying Erwin quartzite. The structure is monoclinal, the quartzite dipping 45° SE. In the valley bottom Shady dolomite outcrops nearly horizontally in the bottom of the Bumpass Cove syncline. The deposit trends northeast, parallel with the strike of the rocks, and is opened

for a distance of one-half mile by pits, shafts, and cuts to depths of about 20 feet, the indications in which are at least encouraging. The openings in the surface wash on the terrace carry more iron ore than manganese, but larger amounts of manganese ore may occur at greater depth in the residual clay beneath.

The ore consists largely of psilomelane in nodules and small lumps of irregular size and form. It contains also a considerable amount of soft black, pulverulent ore consisting of pyrolusite and wad, locally called "plumbago." Crystalline manganite in the form of "needle" ore is also present in considerable amount. Some nodules several inches in diameter are composed of psilomelane and needle manganite arranged in alternating concentric layers, and a piece of one of these is reproduced in Part I of this report as Fig. 3A (p. 162).

The most southwestern prospect is just east of the Clark Creek Gap road. It is a shallow pit which runs northeast into the terraced hill about 50 feet above an outcrop of Erwin quartzite and exposes clay containing chert and sandstone fragments. Psilomelane nodules and soft pyrolusite ore are present sparingly. Other small pits scattered over the top of the hill have not been sunk through the thick cover of wash and contain chiefly iron ore. Whether manganese ores occur in depth was not determined. An old iron-ore pit scars the east slope of the hill, and at its northeast side a deep pit has been recently driven in from the small ravine. Considerable good ore shows in its walls and it was here that the large nodules of needle ore were obtained. In the ravine manganese occurs in banded clay in the face of an old iron pit. The clay is full of cherts and is probably residual from the basal part of the Shady dolomite. On the slope above this pit a ledge of brecciated quartzite, which has been cemented and partly replaced by manganese ore, has been opened by a pit. It is too siliceous to be worked as an ore, however.

There are several prospects on the terraced hill to the northeast, especially at its northeast side where there are two deep cuts exposing considerable ore, some of which is good needle ore. Bands 6 to 8 inches thick of black wad alternate with yellow buckfat clay, dip northwest at a low angle into the hill, suggesting a syncline. A large ledge of brecciated ferruginous quartzite to the northeast across the ravine is apparently the Erwin quartzite on the southeast limb of the syncline which is rising northeastward and terminates the syncline in that direction. Farther northeast, in Washington County, manganese is

being prospected for by a Keystone churn drill, the lower slope of the mountain being systematically drilled to a depth of about 200 feet for zinc and lead and incidentally manganese.

Although no manganese ore has been shipped, several tons of high grade ore are at the railroad and enough such ore is showing in the walls of the prospects to warrant mining on a small scale. The tops of the terraces, where the thickest deposits may be expected, have not been tested in depth because of the thick cover of wash, and deep bore holes or wells should be sunk there to thoroughly test out the deposits. If no large pockets are encountered the deposits will not warrant an expensive plant, but probably can be worked on a small scale with profit at the present prices.

WASHINGTON COUNTY.

Washington County, of which Johnson City is the county seat, lies west of Carter and Unicoi counties, and includes a small part of the Appalachian Mountains along its southeast border, in which manganese ores have been reported. Those in Bumpass Cove have already been referred to. Vague reports of a deposit at the head of Dry Creek, between Cherokee and Buffalo mountains, were heard, but as no development work has been done, it was not visited. A small area there is underlain by clay residual of the Shady dolomite inclosed in a syncline faulted on the southeast side, according to the geologic map of the U. S. Geological Survey,[1] and is therefore favorably located for such deposits.

GREENE COUNTY.

Greene County, of which Greeneville is the county seat, lies west of Washington County. Its southeast boundary is also the State boundary which follows the crest of the Bald Mountains. It contains several manganese deposits, all of which occur 10 to 14 miles south of Greeneville in the southern part of the county in the intermontane valleys of the Appalachian Mountains. The deposits include the Hayesville, Sylvia, Lamb, and Payne prospects, all in the Hayesville district.

HAYESVILLE DISTRICT.

The Hayesville district includes the area around Hayesville, but chiefly the region south to the State line. It centers around the old iron mines and furnace at Hayesville.

[1]Roan Mountain folio of the Geologic Atlas of the United States, by Arthur Keith.

Hayesville Prospect.—Hayesville and the old Hayesville furnace are 10 miles in direct line south of Greeneville, or about 14 miles by road. The deposits are a half mile southwest of the furnace at the site of the old Hayesville iron mine. The property is owned by the Unaka Development Co., of Greeneville, Tenn., which is at present doing exploratory work under Leroy Park, of Greeneville, superintendent. About a year ago the Virginia Iron, Coal, and Coke Company opened up many new pits and tunnels on the property, exposing iron ore and some manganese.

The iron and manganese deposits occur on a terraced hill at the northwest foot of a low spur of Bald Mountain. Dolomite exposed on the lower north slope of the hill dips 80° S, probably overturned, and also occurs at the south crest and on the south side of the hill. Quartzite masses at the crest and in the dump from the shaft suggest that the body of the hill is Hesse quartzite, but this was not fully determined. The geology is evidently complicated but the the structure appears to be a local sharp anticline of Hesse quartzite faulted and overthrust northwestward on to Shady dolomite, with a shallow syncline on the southeast inclosing Shady dolomite between the small hill and the main mountain slope.

This low hill southwest of the furnace is covered with old workings for iron, chief of which is a tunnel 750 feet long running northwest into the hill from a small branch of Back Creek and connecting with a shaft 180 feet deep from the top of the hill. Several large open cuts on both the north and south slopes of the hill mark the extent of the iron mining industry. The overburden covering the iron-ore ledges and bedrock is 10 to 30 feet of clay and wash, which contain small fragments of iron ore and some manganese. Most of the iron ore mined is said to have contained about 5 per cent manganese.

A short distance north of the shaft, down the slope, at an elevation of about 1,650 feet, is a large old open cut 100 feet wide and 80 feet high at the face. Several tons of soft pyrolusite ore were recently taken out and lie on the floor of the pit. The ore is partly of fine gravelly or shot type and partly soft and powdery. Some ore was bagged and shipped to New York for paint and a substitute for lamp black. It is too low grade for chemical ore, although it was reported to have assayed more than 50% manganese with but little iron

or silica. Some harder psilomelane and iron balls with soft waddy ore inside are also present in the old pit. The deposit lies in pockets in residual clay and chert of the Shady dolomite and was mined from short tunnels and pits near the bottom of the large pit. In one pit the soft waddy clay stands vertical, parallel to a 3-inch seam of barren clay, probably representing original bedding. A ledge of weathered buff chert exposed in the upper part of the old pit face, coated and seamed along joint planes with manganese, is also about vertical, dipping 80° S, probably overturned. A tunnel recently driven southward into the face of the big open cut penetrated a considerable amount of soft clayey and ferruginous wad, and farther into the hill encountered some excellent manganese ore. Up to the present time not a large amount of high-grade ore has been found, but there is a possibility that a good body may yet be encountered. However, the ore is somewhat inaccessible because of the great depth at which it occurs, and much of the ore is soft and is expensive to mine because of the care necessary in handling it.

In the most southerly well about 30 feet deep, on the saddle connecting the hill with the main mountain and close to the quartzite of the mountain, a lump of very high-grade psilomelane was struck. It lies in yellow clay derived from the Shady dolomite, and fresh dolomite is encountered in adjacent pits. Judging from the hundred or more prospect pits that have been sunk, the Hayesville tract is mainly an iron ore property, although much of the iron ore is manganiferous and good manganese ore has been encountered in several places. Further prospecting may possibly bring to light workable bodies of high-grade manganese ore.

Sylvia Prospect.—The Sylvia prospect is 11 miles south-southwest of Greeneville and 4 miles southwest of Hayesville furnace. It was operated as an iron mine by the old Hayesville Iron Co. prior to 1874 and has only recently been opened for manganese by Leroy Park and J. C. Park, of Greeneville, who have acquired the property.

It is on a terraced spur at the northeast end of Meadow Creek Mountain at about 2,170 feet in elevation. This bench is a remnant of the old valley floor. The old mine is reached by a good wagon road from Cove Creek to the east.

The deposit occurs in residual clay of the Shady dolomite close to the contact with the underlying Hesse quartzite which forms the

spur just back of the mine. A small knob north of the mine is composed of soft sandstone which is nearly vertical and probably represents a small anticline of the underlying quartzite, so the structure at the mine seems to be a small local syncline. This structure is not certain, however, as the geology is complicated by faulting. A shaft and several pits not over 12 feet deep have recently been dug in the old iron opening, but they had fallen shut. A little manganese ore disseminated in yellowish-red clay and fragments of buff chert with white wavellite seams are on the dump. The ore is psilomelane of good grade in small nodules and irregular fragments. Samples of ore are said to have analyzed 52% manganese, but the run of ore will not average that much. The quantity of ore seems very small and unless further prospecting shows up a better deposit it will not be profitable to work.

Lamb Prospect.—The Lamb prospect is near the south corner of the county about 13 miles south of Greeneville and 2½ miles south of Limestone Springs. It is on the Scott Lamb farm, south of the Allen Stand road, in an open field a short distance west of the tenant cabin.

It is in the lower northwest slope of the mountains just east of Cove Creek, about 1,800 feet in elevation, in the saddle of a terraced ridge which is a remnant of an old valley floor.

The deposit occurs in red clay residual from the Shady dolomite near the contact with the overlying Watauga shale, the structure being monoclinal. It is opened by a shallow shaft sunk many years ago for manganese, it is said. The shaft is now caved. A specimen of fairly good nodular psilomelane was found on the dump. It is reported that a series of old manganese prospects extends eastward from the shaft for one-half mile or more, some of which looked encouraging.

Payne Prospect.—It is reported that good ore has been obtained from property owned by Henry Payne and opened by Leroy Park of Greeneville. It is said to be on the south slope of Meadow Creek Mountain near its summit and to be 9 miles from the railroad. It was not visited by the writers and its geologic relations and possibilities are not known.

COCKE COUNTY.

Cocke County, of which Newport is the county seat, lies southwest of Greene County adjacent to the North Carolina State line. The southeastern part of the county is mountainous and the manganese deposits occur at the foot of the mountain slopes on or near remnants of the old valley floors of the French Broad and Pigeon rivers. They occur in the Del Rio and Newport districts, but mention is made by Harder[1] of manganese ore also near Cosby, west of Denny Mountain.

DEL RIO DISTRICT.

The Del Rio district is in the eastern part of the county in the heart of the mountains around the town of Del Rio, which is on the French Broad River and on the Morristown-Asheville line of the Southern Railroad. The more important mountains in the district are the Meadow Creek, Neddy, and Stone mountains on the northwest and the northeastward continuation of the Great Smoky Mountains on the southeast, the crests of which is followed by the State line.

Wood Mine.[1]—The Wood mine is 5 miles northeast of Del Rio on the south slope of Meadow Creek Mountains. It is owned by Nick Wood of Del Rio. It was last worked in 1906 by J. N. Adams and associates of Charleston, Tenn., at which time some ore is reported to have been shipped. It is on the steep south slope of the mountains, at an elevation of 2,170 feet. It is in brownish to chocolate-colored residual clay resting on the Hesse quartzite near its contact with the overlying Shady dolomite and seemingly at or near a parallel east-west fault.

The principal opening is a pit 15 feet in diameter by 8 feet deep, which formerly was somewhat deeper. Its approach is a 50-foot cut which runs N 60° E into the hill. Ore is shown more or less throughout the walls of the pit and the cut, and about two tons of shipping ore and 10 or 12 tons of wash dirt lie on the dump. The ore is almost entirely of the coarse hard nodular or lump type. It consists almost wholly of massive psilomelane with very little concentric banding or botryoidal and stalactitic forms. Much of the weathered portion

[1]Harder, E. C., Op. Cit., p. 76.

[1]Descriptions of the Wood, Adams, Blanchard, and Waddell mines and of the Huff and Lamb prospects, the latter in Greene County, are by F. C. Schrader.

of the ore is more or less pitted. This feature is also present in the croppings at the southwest edge of the pit where massive coarse bouldery ore stands 6 to 8 inches above the surface for a width of 6 feet. The preservation of the croppings seems to be due to the presence of quartz and wavellite in the ore. Wavellite is also more or less plentiful throughout the ore, where it seems to be secondary in the form of small irregular stringers and veinlets filling fractures, small lenticular bodies, and beads in cavities. On flat surfaces of the ore it occurs as fan-shaped bodies of radiating fibrous crystals up to one-half inch in length. The ore probably contains considerable phosphorus from the wavellite.

The manganese deposit trends a little north of east parallel with the mountains and seems to dip to the southeast approximately conformable with the country rock which is exposed in Laurel Branch Valley to the southwest. Shallow prospect pits and trenches dug at intervals in the gently rising surface for a distance of 400 feet east of the mine show traces of ore similar to that at the mine.

The deposit probably contains considerable manganese ore, but owing to the presence of phosphorus in the ore and the distance of haulage, 4 miles of which is over a rough mountain road, it cannot at present be profitably worked.

Adams Mine.—The Adams mine is 2 miles northwest of Del Rio in the steep lower slope of the northeast end of Stone Mountain. at an elevation of 1,600 feet. It is 400 feet above the railroad and about 3/10 of a mile distant. It is owned by John N. Adams of Charleston, Tenn. It was last worked in 1908 when it is reported to have produced and shipped to Johnson City, Tenn., for the manufacture of polish. 8 carloads of ore, totalling about 300 tons, which is probably an overestimate. The ore was shipped in bags, unwashed, and is said to have averaged 47% manganese.

The deposit occurs in residual clay resting on the Hesse quartzite near its contact with the overlying Shady dolomite which seems to be also a fault contact. Much of the quartzite is deep yellowish brown from impregnations of limonite. The deposit dips westward. into the mountain and is reported to have a thickness of more than 50 feet, its lower limit not having been reached in a 40-foot shaft sunk from the bottom of a cut 15 feet deep. Croppings and surface debris indicate that the deposit probably extends southwestward up the moun-

tain slope. The containing clay is mostly light brownish, but is variegated by small to large masses which are chocolate colored or black. It contains fragments of partially decayed quartzite and cherty material resembling a fault breccia.

The ore consists chiefly of layers or beds of massive, soft, sooty wad and pyrolusite, with considerable hard nodular material composed of manganite and psilomelane. The manganite occurs mainly in radial fibrous needle crystals in concentric bands alternating with hard blue psilomelane. It is said that only the soft ore was shipped for the manufacture of polish. A ton or two of soft shipping ore and three or four tons of unwashed ore lie on the dump.

Blanchard Mine.—The Blanchard mine is about 2 miles northwest of Del Rio, a half mile south of the Adams mine on the same spur of Stone Mountain. It is owned by William Blanchard of Del Rio. It was last worked by the Commercial Mining and Milling Co. of Del Rio in 1902, when it is said about 200 tons of unwashed ore averaging 47% manganese was shipped. It is now being operated by the Barium Lithophone Co. of Philadelphia, whose development consists of five or more openings in the steep east slope of the mountain, of which the more important are 250 feet higher than the Adams mine, at elevations between 1,750 and 1,900 feet.

The openings are in the Hesse quartzite or perhaps in transitional beds at the contact with the Shady dolomite, which seems to be also a fault contact. They appear to be in the southward continuation of the mineral zone at the Adams mine. The ore is principally hard, concretionary, nodular manganese ore, but includes also some manganiferous iron ore.

At one of the main openings, in the north side of an eastward-sloping spur at 1,850 feet elevation, the deposit seems to consist of a six-foot bed of good nodular manganese ore in soft white sandstone which dips 40° to the southwest. The ore adheres to the walls of sandstone and partially impregnates it. About 50 tons of ore of the 1902 shipment is reported to have come from this opening. At another opening on the opposite or south slope of the spur, 1,790 feet in elevation, conditions are similar except that the workings are more extensively caved and overgrown with vegetation and the quartzite includes a fine conglomerate with small white quartz pebbles. One hundred and forty tons of ore from this opening were included in the

1902 shipment, and the ore is said to have averaged 47% manganese. Approximately 4 tons of ore still on the dump is of the good concretionary nodular type and consists of hard massive psilomelane and of crystalline manganite with radial and parallel fibrous needle structure. One lump is 2½ feet in diameter. Some specimens show mutually facing, comby structure apparently denoting deposition in fissures.

The next opening a short distance down the ridge to the southeast, is a tunnel. The deposit here consists mainly of a 2½-foot thick (?) tabular body of ore in red clay and sandstone, dipping 60° WSW into the mountain. The walls consist chiefly of altered, liver-colored, ferruginous silica rock which the ore deeply penetrates and replaces. The ore is similar to that just described, though in places it is slightly waddy and siliceous from finely crystalline glassy quartz lining small irregular cavities. Some of the ore has stalactitic structure. The tunnel, which was badly caved at the time of visit, is reported to have been more recently reopened and conditions looked encouraging. From this opening some high grade ore was shipped. Several tons of concretionary nodular ore lie on the dump.

Waddell Mine.—The Waddell mine, also known as the Pigeon Roost mine, is 3½ miles west of Del Rio and 1½ miles south of West Myers station on the Southern Railroad. It is owned by John B. Waddell, of Springfield, Mo. It was worked in 1892 by Sugars and Oliver, but so far as learned no ore was shipped. In the early part of 1918 it was worked by the Southern Manganese Corporation, P. J. Harkins being in charge, who reports that 10 tons of manganese ore were taken out, which exhausted the deposit.

The mine is on the south slope of an eastern ridge of Stone Mountain, at an elevation of 1,900 feet, on the west side of a gulch that drains southward into Big Creek. A newly made mountain wagon road from the Dicky kaolin mine nearby to West Myers station passes the mine.

The deposit occurs in a dark-reddish ferruginous quartzite, which is believed to be the Nebo quartzite, and in overlying clay which may be residual from Hiwassee slate. The geologic relations are not fully known. At the time of visit a caved pit 25 feet in diameter, which originally may have been 25 or 30 feet deep, was the only

opening. The ore bed seemed to dip to the northwest and appeared to be 8 or 10 feet in thickness.

About 20 tons of ore on the dump consists chiefly of hard psilomelane nodules or bouldery masses in which radial and parallel, aggregate, stalactitic structure is dominant. The surfaces of some fragments are blistery or botryoidal on a small scale. The ore heavily incrusts joint planes and fracture surfaces of the quartzite and commonly penetrates or impregnates it to the depth of several inches. At a point several hundred feet to the northwest of the mine dark wad in clay is exposed in shallow cuts of the wagon road to the kaolin mine.

Huff Prospect.—The Huff prospect, commonly known in the region as the Huff mine, is north of Waddy Mountain, on the Newport-Del Rio wagon road about 4 miles from Del Rio. It is in the lowland north of the road on the farm of Aleck Huff of Del Rio.

It was first opened for manganese in 1892 by Mr. Icewall, of Atlanta, Ga., who excavated the large pit just northwest of the barn near the road, but no ore was shipped. The pit is in Watauga shale near its contact with the underlying Shady dolomite. The shale outcrops a short distance to the west and there dips 60° E.

In 1918 John N. Adams, of Charleston, Tenn., is reported to have dug the 50-foot open cut or trench with a face 8 feet high in the barnyard. This cut is in red clay containing black or dark-gray angular blocks of the so-called ore ranging up to 2 feet in diameter. The so-called ore, many tons of which, from both the old pit and the newer cut, appear in the stone fences inclosing the barnyard and adjoining fields, is a fine-grained chert stained and slightly impregnated with manganese, and contains 75 to 80% of silica and very little manganese or iron. Some of the material is finely porous with scattered cavities one-half inch in diameter, closely resembling slag. Some of the cavities and crevices are thinly coated with crystalline manganite. It is too silicious to be an ore of manganese and has no commercial value.

Long Creek Prospect.—Long Creek prospect is on the east side of Long Creek, one-half mile northeast of the Del Rio-Newport wagon road, and 3 miles north-northwest of Del Rio. It also is on the farm of Aleck Huff of Del Rio.

It is on the side of a low spur at the southwest end of Meadow Creek Mountains, and is in chert and clay residual from the Shady dolomite at its contact with the underlying Hesse quartzite. The beds at the prospect seem to be vertical along a fault. In the creek near the road fresh Shady dolomite dips 45° SW.

The developments are old workings that have caved. A tunnel, which runs north into the hill from the small branch of Long Creek, follows a ferruginous chert, which lies at the contact of the quartzite on the east and dolomite clay on the west, which is apparently a fault line. Several slumped trenches show reddish clay and a very small amount of psilomelane on the dumps. Masses of iron ore, which may be manganiferous, up to 1½ feet in diameter occur as float.

NEWPORT DISTRICT.

The Newport district includes the area around the town of Newport in the western part of the county. The known deposits are on the north end of English Mountain.

Newport Mine.—The Newport mine, formerly known as the Yellow Springs mine and the Carson Springs mine, and also spoken of as the English Mountain mine, is at the north end of English Mountain 4 miles southwest of Newport. The property is part of the John Sant & Son estate of East Liverpool, Ohio. The mine is being operated by the Newport Manganese Corporation, of Newport, of which the Southern Manganese Corporation, of Birmingham, holds a controlling interest. Analyses of carload lots of high-grade ores shipped in 1918 ran 42.85% manganese, 6.25% iron, .8% silica. Carload lots of the poorer ore ran 34.78% manganese, .11% iron, 12.10% silica. Complete analyses of some of these shipments are reported as follows:

Moisture	5.77	4.68
Manganese	37.57	33.89
Fe	7.44	8.63
SiO_2	9.42	13.73
Al_2O_3	6.51	6.55
$CaCo_3$	.37	1.05
$MgCo_3$	.40	2.41
BaO	2.10	2.63

Recent reports from the mines state that mining is being done from 4 tunnels, the end of the lower one being 55 feet below the surface. The tunnels follow an irregular bed containing masses of high-grade ore, ranging up to 300 pounds in weight. The washer

running only every other day produces 50 tons of ore a month, which carries 40% manganese.

The deposits occur in clay residual from basal beds in the Shady dolomite. The mine is described in detail as one of the types of manganese deposits in the State in Part I of this paper (pp. 177-179).

Jones and McMahon Prospect.[1]—The Jones and McMahon prospect is 4 miles west-southwest of Newport and about one-half mile east of the Newport mine. It is on a terrace at the foot of the north end of the east prong of English Mountain, east of Sinking Creek Gap. The property is owned by Jones and McMahon of Newport. The prospect consists of manganese ore float on the surface, no openings of any consequence having been made. It was not visited by the writers. The ore is reported to be of irregular and stalactitic form and very sandy. The deposit occurs in wash and possibly in the underlying clay derived from the Shady dolomite.

Raines Mine.—The old Raines mine is 3 miles southwest of Newport and about 1 mile east of the Newport mine. It is on a terrace at the northeast end of English Mountain, which is covered with surface wash and is underlain by clay residual from Shady dolomite. The mine was opened years ago for a short time. The development exposes brown sandstone replaced by small specks and stringers of manganese ore which in places is concentrated enough to be a low-grade siliceous ore. Irregular masses of psilomelane are scattered through the overlying clay.

The George L. Gray farm, on which the old Raines mine is located, has recently been bought by Barney Hurley of Newport, who expects to develop it.

HAMBLEN COUNTY.

Hamblen County, of which Morristown is the county seat, lies west of Greene County and northwest of Cocke County. Manganese ore is reported at several localities in the vicinity of Morristown, chiefly in the chert ridges northwest of the city. They are in the Boatman Ridge district. Deposits in red clay southeast of Morristown referred to by Penrose[1] were not visited.

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[1]The descriptions of the Jones and McMahon prospect and Raines mine are largely from E. C. Harder, Op. Cit., p. 76.

[1]Penrose, R. A. F., Op. Cit., p. 416.

BOATMAN RIDGE DISTRICT.[2]

The Boatman Ridge district is northwest of Morristown, comprising several parallel, northeast-trending chert ridges on which manganese ore has been reported.

Prospects Northwest of Morristown.—Several prospects occur in the chert ridges northwest of the city, particularly on top of Boatman, or River, Ridge. On land in which J. N. Lotspeich, of Morristown, is interested, 3 miles northwest of the city, the top of the ridge shows manganese and manganiferous iron at a number of places and has been prospected by shallow pits. It is reported by Mr. Lotspeich that from one large mass of ore taken out several years ago 2 carloads of manganese ore were shipped. At present but little ore is showing in the slumped pits.

Two other prospects farther southwest on the same ridge are on adjoining farms of Monroe Mays and G. N. Ivy, 5 miles west of the city. The pits are shallow and slumped, so that little ore is to be seen. Other prospects are reported on the northeast end of this ridge south of the Noeton ferry near the Tate Springs road.

The deposits are all in residual chert and clay of the Knox dolomite, close to yellow shales and limestones of the underlying Nolichucky shale. The rocks dip 15° to 20° SE. The ore is psilomelane in chert which is brecciated and cemented and partly replaced by the ore. The amount of ore seems small and is highly siliceous, as the chert cannot be readily separated from the ore. Iron ore is also associated with it. None of the prospects are promising.

Curry Prospect.—The Curry prospect is 7 miles northeast of Morristown on the Bright Mills road. It is in the chert hills of the Knox dolomite, at about the same horizon as those on Boatman Ridge. Here a small amount of psilomelane and iron ore occur as a fissure filling and replacement of the chert. The showing indicates that the deposit has little value.

GRAINGER COUNTY.

Grainger County, of which Rutledge is the county seat, lies west of Hamblen County, Holston River forming the boundary line. It is mostly valley land but its western part is crossed by Clinch and Log

[2]The descriptions of prospects in this district are largely from notes by Arthur C. McFarlan of the Tennessee Geological Survey.

mountains. Manganese is reported from several localities, three of which are in the Rutledge district and two in the Washburn district.

RUTLEDGE DISTRICT.

The Rutledge district includes the area around Rutledge, the known prospects lying in the hilly Richland Knob country southeast of the town.

Rutledge Mine.—The Rutledge mine is 2 miles southeast of Rutledge on the farm of J. H. Lowe of Rutledge, and is being operated by J. S. Swann of Knoxville. The deposit occurs in residual clay and chert of the Knox dolomite close to its contact with the underlying shale. The analysis of shipments reported in 1918 ran 25.86% manganese and 3.57% iron. On account of the low grade and small quantity of ore, it was reported that the mine would probably be abandoned. It is described in detail as one of the types of ore deposits, in Part I of this paper (pp. 182-184).

Harmon Prospect.—The Harmon prospect, on the farm of Joe Harman of Rutledge, is 2 miles southeast of Rutledge. It is leased by J. S. Swann of Knoxville, who planned to open it up.

At the time of visit the deposit was exposed in the bed and bank of a small branch of Richland Creek. It occurs in yellowish and dark-banded clay apparently of the Nolichucky formation just below the Knox dolomite, the rocks dipping 10° SE. A 3-foot bed of banded clay with dark manganese laminae and a little ore crosses the bank diagonally, and considerable psilomelane float ore lies on the surface. The pebbles in the stream gravels of the valley bottom are cemented with black manganese ore, and the present waters of the stream blacken the pebbles in it, showing that the streams are still carrying manganese in solution.

Other Prospects in the Richland Knobs.—Manganese float ore is reported on the farm of B. F. Young, of Knoxville, 6 miles south of Rutledge and 2 miles south of Doyal postoffice. It is in the Knox dolomite and occurs as small fragments in the soil mixed with pieces of chert. Its quality or quantity is not known as it has not been prospected. It was not visited by the writers or by Arthur C. McFarlan.

Samples of manganese ore have been found on several other farms southwest of the Rutledge mine, one of which, about 6 miles distant, looked so favorable that J. S. Swann had secured an option on the

property and expected to develop it. It is on top of the high front knobs similarly situated to the Rutledge mine.

WASHBURN DISTRICT.

The Washburn district includes the area around Washburn on the Knoxville-Middlesboro line of the Southern Railroad, particularly the valley country northwest of Clinch Mountain. Indications of manganese are reported at several localities.

Wallen Prospect.—The Wallen prospect is 5 miles northeast of Washburn, on the lower south slope of Copper Ridge, 1½ miles northeast of Puncheon Camp. It is on the William Wallen farm, and the mineral rights were leased by R. B. Bundren, of Washburn. It is undeveloped and consists merely of a few large masses and smaller sized fragments of very good psilomelane ore which are found at the surface of cultivated fields. One lump of ore weighing 60 pounds is said to have been found. The psilomelane is solid and massive and contains a little manganite and apparently braunite. The latter mineral is not certainly identified because of the difficulty of distinguishing it in the massive crystalline form. Some iron ore is also present in the dark-red clay soil. The ore occurs in the soil resting on Knox dolomite near its contact with the overlying Chickamauga limestone, which dips about 40° SE. Although the ore is of high grade, the indications are that there is very little ore present.

Frye Prospect.—The Frye prospect is 1½ miles northwest of Washburn and the same distance southeast of Liberty Hill, both on the Knoxville-Middlesboro line of the Southern Railroad. It is on a small spur on the northwest slope of Copper Ridge at about 1,400 feet elevation, not far from Williams Creek. The land is owned by Charles Frye of Washburn. It is undeveloped and consists merely of nodules and small fragments of manganese ore and waddy clay in the soil of cultivated fields on the Frye and neighboring farms and similar ore is reported on John Dozier's farm 3 miles southwest.

The chert and clay in the soil are derived from basal portions of the Knox dolomite, and the underlying Nolichucky shale outcrops in the run near by. Some of the manganese ore has what appears to be a fine shot-like structure which suggests that it may be pseudomorphic after oolitic chert, also present in the soil and stained by manganese, but the structure is simply layer upon layer of botryoidal psilomelane.

Considerable crystalline manganite is present with the psilomelane and the ore is of high grade, but there is apparently very little ore present.

JEFFERSON COUNTY.

Jefferson County lies south of Grainger and Hamblen counties, and, like the latter, is crossed by many low ridges. Only one manganese prospect is reported and its location in the county has not been determined.

JEFFERSON DISTRICT.

The Jefferson district embraces the hills and valley around Jefferson, where manganese may be expected to occur in the chert of the Knox dolomite.

Currens Prospect.—Ore has been reported on the property of George Currens of Jefferson City. The location was not determined, but it is believed to be a deposit in the chert of the Knox dolomite which composes many of the ridges of the valley in the neighborhood. It was not visited by the writers and a detailed description cannot be given.

SEVIER COUNTY.

Sevier County lies southwest of Cocke County along the southeast border of the State. Sevierville is the county seat. The southern half of the county is mountainous, including the northwest slope of the Great Smoky Mountains, the summit of which is followed by the State and county line. The northwestern half is partly hilly. The only manganese deposits known in the county is at the East Fork mine, at the edge of the mountains. It will be described under the East Fork district.

EAST FORK DISTRICT.

The area within the mountains around East Fork of Little Pigeon River, where deposits of manganese are likely to be found, will be included in this district.

East Fork Mine.—The East Fork mine is on the East Fork of Little Pigeon River near East Fork postoffice, 13 miles southeast of Sevierville. It is owned by the Tennessee Manganese Co. of Knoxville which is at present developing it. The mine is on a terraced spur on the southeast slope of a prominent ridge at an elevation of about 1,200 feet. The ore is a carbonate of manganese in dolomite beds in Hi-

wassee slate. The property is described in detail as one of the types of ore deposits in Part I of this paper (pp. 194-198).

KNOX COUNTY.

Knox County lies northwest of Sevier County. It is crossed by several low ridges which trend northeast across the valley. A few manganese prospects are reported from the Knoxville district, south of Knoxville, and one from the Copper Ridge district, northwest of Knoxville.

KNOXVILLE DISTRICT.

The Knoxville district includes the area around Knoxville, especially the lines of Red Hills south, southwest, and southeast of the city, where manganese ore has been reported at several places.

Prospcts Southwest of Knoxville.[1]—Several belts of Red Hills lie south of Knoxville, two of which extend many miles to the northeast and southwest. These hills have long been known to carry some ore, high-grade hematite iron ore being the most common but very pure manganese ore is also present in many places. Further prospecting should be done along both belts, particularly along the contact of the red Tellico sandstone and the underlying Holston marble, where rich deposits of ore occur farther southwest, but up to the present the indications in the Knoxville district are not favorable.

The Fitzgerald prospect is about 6 miles southwest of Knoxville and 3 miles south of Bearden station on the Southern Railroad. It is on the farm of J. H. Giezentanner and is being worked on shares by Paul Fitzgerald. It has only recently been opened to the depth of 10 feet, and about 15 tons of ore had been taken out and lies on the dump. The ore has considerable clay in it and is of medium grade. Brown iron ore also occurs with it. The ore is in a shaly phase of the Tellico sandstone whose dip is generally to the southeast but varies greatly. It occurs in thin irregular seams which follow the bedding planes of the rocks. Near the northern boundary of the property considerable sandy float ore occurs, and on the adjoining farms of Mrs. W. C. Badgett and L. F. Currier large amounts of iron ore are reported.

On the farm of J. C. Green, 2 miles southwest of Bearden station, a small amount of manganese float ore occurs scattered over the

[1]These descriptions are largely from notes by Arthur C. McFarlan.

red hill and a pit 3 feet deep has been dug exposing similar ore. It is mostly light-weight pyrolusite and waddy clay in a small seam in the clay. The Tellico sandstone on the hill dips 58° SE.

On the adjoining property to the south, C. S. Morel's farm, a little psilomelane and sandy iron-ore float occur. Northeast of the Green property a large amount of good hematite occurs on L. D. Tyson's farm and several large pieces of high-grade manganese ore have also been found.

COPPER RIDGE DISTRICT.

The Copper Ridge district includes the prospects in the belt of chert ridges lying northwest of Powell, which trend northeast. Only one prospect is here described.

Haworth Prospect (reported).—The Haworth prospect is reported to be 8 miles northwest of Knoxville and 2 miles northwest of Powell on the Coster Division of the Southern Railroad. It is on the farm of W. L. Haworth of Knoxville on the top of Copper Ridge. There has been no development of the property, the showing of ore consisting of float psilomelane cementing and partly replacing chert from the Knox dolomite. It was not visited by the writers or by Mr. McFarlan.

ANDERSON COUNTY.

Anderson County is northwest of Knox County. Clinton is the county seat. The northwestern part is mountainous, being occupied by the Appalachian Plateau, a dissected or eroded plateau composed of coal-bearing rocks. In the southeastern valley portion a few prospects of manganese ore have been reported, chiefly along Pine Ridge north of Clinton.

PINE RIDGE DISTRICT.

Pine Ridge is a low ridge trending northeast along the foot of Walden Ridge, the front mountain of the Appalachian Plateau. The district known to carry ore lies northwest of Clinton along the ridge for a length of about 3 miles.

Bright and Howell Prospect (reported).—D. M. Bright and D. A. Howell of Knoxville have an interest in a property on the northwest side of Pine Ridge, 5 miles north-northwest of Clinton at the Cane Creek gap in the ridge. A pit has been sunk and is reported to expose good manganese ore. The ridge is composed of shales and sandstones

of the Rome formation, equivalent in part at least to the Watauga shale farther northeast in the valley, which dips southeast in general. According to the geologic map in the U. S. Geological Survey Atlas[1] it is faulted along its northwestern side against Chickamauga limestone. The ore apparently is associated with this fault. It was not visited by the writers or by Mr. McFarlan.

Manganese ore is reported to show in the road cut through Pine Ridge 3 miles northwest of Clinton. It is believed also to be in the Rome formation, but it is not prospected.

Wallace Prospect.—A prospect is reported near Coal Creek on the farm of Hack Wallace, of Clinton, Tenn. It is probably also on Pine Ridge, although its exact location is not known. It was opened in 1914 and 1 ton of ore analyzing 48% manganese, 1.60% iron, and 8.0% silicia was shipped. Nothing further was done with the property until 1918 when it was leased to T. F. Narramore who is reported to have started developing. It was not visited by the writers and the relations of its deposits and the character of its ore are not known.

Blount County.

Blount County, of which Maryville is the county seat, lies southwest of Sevier County along the southeast border of the State. The southeastern part of the county is mountainous, the State and county boundary following the top of Great Smoky Mountain which is over 5,000 feet in altitude in places.

Several deposits of manganese ore are reported in the county: the Townsend prospect in the Tuckaleeche Cove district, the Louisville mine in the Louisville district, several prospects in the Chilhowee Mountain district, and prospects northeast of Greenback.

TUCKALEECHE COVE DISTRICT.

Tuckaleeche Cove is a flat-bottomed valley on Little Pigeon River within the mountain area southeast of Maryville. It is hemmed in on the southeast by high steep mountains and on the northwest by lower ridges through which the river passes in a gorge. Manganese ore is reported at only one place in the cove.

[1]Briceville folio, by Arthur Keith.

Townsend Prospect.[1]—The Townsend prospect, known also as the Webb prospect, is in the eastern part of the county in Tuckaleeche Cove, a half mile north of Townsend station on the Knoxville-Elkmont branch of the Southern Railroad. The pospect is across Little Tennessee River from the railroad, which is not here bridged, on the farm of A. H. Webb. On the west slope of a hill just south of the farm house a large amount of float ore is present, chiefly in small fragments which were fairly abundant in gullies that trench the surface. The ore is a good grade of psilomelane of high specific gravity. Seams of black manganiferous clay ranging up to 4 inches in width are also exposed in the gullies. The ore seems to follow along a small ridge trending northeast. On the adjacent farm of M. A. Webb fragments of psilomelane cementing and replacing chert occur with iron ore, which was once mined. The surface is strewn with well-rounded stream-worn quartzite cobbles ranging up to 6 inches in diameter. The geologic relations are not known, but the region is underlain by Knox dolomite, and the manganese ore is probably derived from the weathering of cherty dolomite.

LOUISVILLE DISTRICT.

The Louisville district includes the lowland around Louisville, southwest of Knoxville. Manganese ore is reported from the hills with deep red soil in this region, but only one deposit has been worked or prospected extensively.

Louisville Mine.—The Louisville mine is in the northwestern part of the county 3½ miles southwest of Louisville and less than a mile by road from the Louisville and Nashville Railroad. It is on the J. B. Cox farm and is leased by the Unaka Minerals Co. of Knoxville, of which M. M. Whittle is secretary and E. F. Buffat manager of the mine. It is a new mine, having begun mining in June, 1918. No shipments have yet been reported, but 25 tons of manganese ore had been mined and concentrated in the log washer in operation at the time of visit.

The mine is in the open lowland country of the Tennessee Valley on the gently sloping north side of a low, flat-topped ridge 1,050 to 1,100 feet in elevation. This bench is part of an old valley floor preserved on the tops of the hills in the vicinity. The deposit occurs

[1]The Towensend prospect is described chiefly from notes by Arthur C. McFarlan.

in residual clay of the Chickamauga limestone or Holston marble. Nodular gray limestone of Chickamauga type outcrops both on top of the hill and below the mine with gentle southwest dip. The ore-bearing clay, however, is of the kind derived from marble of the Holston type. The deposit is therefore of the Holston marble type associated with sandy, manganese-bearing beds in the marble similar to those in the red Tellico sandstone above.

The ore-bearing clay is dark chocolate-colored soil and mottled red and yellow clay, about 10 feet thick. It rests on a thin bed of yellow barren clay from one to several feet thick which overlies the bedrock of nodular gray limestone or impure marble. It is overlain by a thin overburden of reddish earthy soil generally a foot thick which is stripped with plow and scraper before mining. Banding in the clay dips 20° NW, about parallel with the surface slope, in part due to creep. Some of the marking is irregular and fragmentary, suggesting brecciation. It may possibly be a solution cavity filling, similar to that at the Vida iron mine near Sweetwater.

The ore is mostly psilomelane and occurs in rough-surfaced nodules, lumps, and grains in dark-clay streaks more or less parallel with the inclined structure. The lumps range up to nearly a foot in diameter. Some of the ore is hard and botryoidal and some is porous with cavities lined with soft black sooty pyrolusite. Ore from the top of the slope above the pit is full of sand grains and is so siliceous that it is not used. Much of the good ore is of the "bird shot" or "fish egg" type consisting of innumerable small, round, shiny, black pellets imbedded in red clay and probably derived from pebble structure in the marble. These small pellets give a dark-brown powder when crushed and are probably ferruginous. Three-fifths of the ore consists of grains and nodules less than one-half inch in diameter, and a jig is needed to save the small particles which pass through a 24-mesh sieve. A small washer for screenings, devised by the management as an adjunct to the main washer, is saving most of it.

The ground is worked by a hydraulic sluice and flume system composed of 5 converging ground sluices. All the dirt beneath the overburden is passed through the washer. As the wash dirt is mined, it is shoveled, or washed by a powerful stream of water from a nozzle, into a ground-sluice and is flumed down the slope to portable flumes which converge into a large hopper at the head of the washer. This requires

more water for steady operation than 120 gallons a minute, the amount now available. The area stripped and now being mined is semicircular with a radius of 70 feet, the deepest part of which, in the middle sluice, is 6 feet deep. The wash dirt passed through the washer is reported to concentrate 8 into 1, 8 tons of mine dirt yielding a ton of washed ore which averages more than 40% manganese.

About a quarter mile south of the mine but on the same property the surface of a hill 1,160 feet in elevation, is covered with good float brown-iron ore which is seamed with red, translucent, radiate, fibrous göthite in layers up to one-half inch thick. On the northwest upper slope of the hill some manganese occurs with the iron ore and seems to be worthy of inexpensive prospecting. A few well-rounded river cobbles are scattered over the surface of this hill and of the lower ridge at the mine. Other hills of this elevation toward the northeast, also covered with deep-red soil, are apparently just as favorable ground for the occurrence of manganese ore, for the geologic and surface conditions are similar to those at the Louisville mine, and should be prospected.

Manganese ore was reported from the Red Hills southeast of the railroad, 2 miles east of the Louisville mine, but as no recent development had been done the deposit was not visited. It is probably at the contact of the Holston marble and the overlying Tellico sandstone, the horizon at which high-grade ore is present farther southwest.

CHILHOWEE MOUNTAIN DISTRICT.[1]

The Chilhowee Mountain district includes that part of Chilhowee Mountain and vicinity in the southern part of the county near Tennessee River where several prospects of manganese ore have been reported.

Prospects Near Chilhowee.—The Sellers prospect is located on the lower southeast slope of Chilhowee Mountain in the southern part of the county 1½ miles northwest of Chilhowee station on the Tennessee and Carolina Southern Railroad. It is on the farm of William Sellers and the mineral rights are owned by J. M. Green and C. A. Benscoater of Knoxville. The two old openings on the place have caved, so that relations could not be observed. Several small pieces

[1]The descriptions of the prospects in the Chilhowee and Greenback districts are largely from notes by Arthur C. McFarlan.

of pyrolusite and manganiferous limonite were found on the old dump, in one of which the manganese minerals occur as cement in a fine quartz conglomerate.

The region is underlain by brownish-gray quartzite and conglomerates, presumably the Hesse quartzite, in which the openings are made. Overlying the sandstone are blue limestone and slate, probably older Hiwassee slate which has been overthrust on it from the southeast.

A small amount of float manganese ore was reported on the Sam McMurray farm, one mile west of Chilhowee, but no openings were made on the property. Henry E. Colton, of Knoxville, is reported to have had an option on a tract about a mile from the McMurray farm, where high grade ore had been found some years ago. Ore is also reported six miles northeast of Chilhowee, on Rufus Miller's place, southeast of Montvale Springs, on the southeast side of Chilhowee Mountain. It was not visited. The relations are probably the same as at the Sellers farm.

GREENBACK DISTRICT.

The Greenback district includes the open-valley country in the western part of the county chiefly northeast of Greenback, where manganese deposits are reported.

Prospects Northeast of Greenback.—A number of prospects, several of which are here described, occur northeast of Greenback, which is on the Louisville & Nashville Railroad. They lie in the clay and chert of the Knox dolomite at or near its contact with the underlying Nolichucky shale. The structure is monoclinal and overturned, for the dolomite dips 50° SE. The ore is a replacement of chert in the dolomite and occurs largely as nodules and fragments mixed with chert in the residual clay and soil.

The Williams prospects are three miles northeast of Greenback. They are on adjoining farms belonging to T. S. and Mrs. A. J. Williams, the mineral rights on which have been recently leased for the development of the deposits. Numerous pieces of good manganese float ore are found in the road and a number of shallow test pits and trenches have been dug on both properties. The ore is psilomelane, small nodules of which lie loose in red residual clay. Some of the nodules are concentrically banded with botryoidal surfaces, and some

have an outer shell of brown-iron ore. Iron ore is also abundant, and the 5 tons of ore on the dump consist chiefly of cherty limonite.

The Curtis prospect is 2½ miles northeast of Greenback, on the farm of T. G. Curtis. A small amount of manganese float ore is scattered over the farm, and southwest of the barn the ore is more plentiful and of higher grade. It is a replacement of chert in the Knox dolomite, the replacement in most cases being complete. Some brown-iron ore is also present with the manganese ore.

The Aiken prospect is 2¼ miles northeast of Greenback, on the farm of John R. Aiken, which adjoins the Curtis property on the southwest. Manganese float ore is abundant near the crest of the hill just back of the house, but no openings have been made.

Manganese ore is also reported on the nearby farm of David Crisp, and also on the J. E. Klepper farm, the mineral rights of which have been recently leased for development; also on the farm of James H. Eakers, of Greenback.

LOUDON COUNTY.

Loudon County adjoins Blount County on the west. The town of Loudon, near the center of the county, on the Tennessee River, is the county seat. The surface is a broad open valley crossed by low hills, which trend northeast.

Manganese deposits are reported at two localities, the Cates prospect in the Loudon district and the Galbraith mine in the Fork Creek Knobs district, the latter district lying largely in the adjoining Monroe County.

LOUDON DISTRICT.

The area around Loudon is included in this district, particularly the Red Hills, covered with deep-red soil, south of the town where iron and manganese deposits are reported. This belt is a direct continuation of the ore belt northeast of Sweetwater, where some of the highest-grade ore is being mined.

Cates Prospect.—The Cates prospect is 1½ miles south of Loudon. It is on the farm of J. K. Cates, of Loudon, and is leased by the Lafollette Iron Company, of Lafollette, Tenn. It is on the crest of a low spur or bench on the northwest slope of a higher hill which trends northeast. The higher hill is composed of chert from the Knox dolomite, which is apparently overthrust on the Holston marble, the ore lying on the Holston near the fault.

The deposit consists chiefly of siliceous brown-iron ore, with no pure manganese ore, some of the iron ore probably carrying some manganese. The siliceous ore covers the surface of the low hill and has been gathered into piles. A trench about 15 feet long and 9 feet deep exposes deep-red sandy clay soil with similar ore. The pit does not reach the bottom of the ore-bearing clay and ore higher in manganese may be struck at greater depth. Probably 50 tons of this ore have been gathered, but none had been shipped. The deposit lies in the red clay derived from Holston marble, which carries rich manganese and high-grade iron ores in places to the southwest, where it is associated with the overlying red Tellico sandstone. The Tellico is not present at the Cates prospect, but comes in just to the northeast and may there carry better ore. The Cates ore may be related to the fault plane and its deposition has been accomplished by mineralized waters circulating along the fault. The deposit appears to be too siliceous to be of value.

FORK CREEK KNOBS DISTRICT.

This district embraces the Fork Creek and adjacent Bat Creek Knobs, which lie chiefly in Monroe County but extend across the southeast corner of Loudon County. Manganese and iron ores are reported from many places on these hills, and the geologic formations are similar to those in the Sweetwater district to the west, where high grade deposits occur. Only the Galbraith mine will be here described.

Galbraith Mine.—The Galbraith mine, also called the Henley mine, is located 8 miles southeast of Loudon and about the same distance from Lenoir, both on the Southern Railway, and 1 mile southeast of Jackson Ferry on the Little Tennessee River, from which point the ore is conveyed by boat down stream to Lenoir. The property is owned by P. C. Henley, of Loudon, and the mineral rights by H. N. Curd, of Lenoir. The deposit was first opened in 1901, and more recently has been leased and operated by Charles Galbraith and Judge Webb, of Knoxville. The operation of the mine was taken over under lease in the summer of 1918 by the Southern Manganese Corporation, of Birmingham. At the time of visit (May, 1918) about 100 tons of manganese ore had been mined and washed, one carload of which had been shipped, part of it to New York for chemical uses, and another carload was being transported to the railroad.

The mine is located on a small knoll 920 feet in altitude on the northwest slope of a prominent ridge, the northeast continuation of the Fork Creek Knobs. The deposit occurs in the Holston marble, which dips 30° SE into the knoll, the latter having a synclinal structure, and was probably formerly capped by Tellico sandstone. The ore is embedded in residual red clay of the Holston marble covered by a few feet of wash, which contains rounded river cobbles and pebbles.

The principal opening at present is a cut into the northwest slope of the knoll 100 feet long by 30 feet wide and 12 feet deep at the face. The ore begins in the superficial wash close to the surface and extends down into the residual deep-red clay. The deeper part of the pit had been filled in, but the ore was said to continue to a depth of 30 feet. Test pits at the side of the cut are not deep enough to determine the lateral extent of the deposit, but some good ore was found. Considerable iron ore covers the surface north of the mine and was formerly mined for iron.

The ore consists chiefly of small lumps of psilomelane with a little soft pyrolusite and some manganiferous iron. The ore is washed in a double-log washer and screened at the mine. The washed ore ranges in size from fine screenings up to lumps 4 inches in diameter, but most of it is less than 2 inches in diameter, and much of it is screenings. It is very clean, and is estimated to average 45% manganese. It is shipped in bags and barrels.

The mine is equipped with a small cable tram about 200 feet long between the mine and the washer. A simple jig was formerly used, but was discarded as unsatisfactory. A flume and pump were being installed to supply a larger amount of water. The ore is of high grade, and although the exposures in the pits showed little ore at the time of visit, other good pockets may likely be found, but a large production cannot be expected as the area of ore ground is small.

Monroe County.

Monroe County, one of the southeastern border counties of the State, adjoining Blount County on the west and Loudon County on the south. Although its southern boundary and the State line follows the crest of the Unaka Mountains, whose foothills occupy the southeastern part of the county, the large northwestern part of the county is valley, crossed by many parallel lines of low hills trending northeast.

Madisonville is the county seat. Manganese deposits occur at several localities, which are grouped into 3 districts.

FORK CREEK KNOBS DISTRICT.—(CONTINUED.)

Mills Prospect.—The Mills prospect is 8 miles northeast of Sweetwater and 2 miles south-southwest of Eve Mills in the northern part of the county. It is on the property of J. C. Mills, of Sweetwater, and is being developed under lease by the Southern Manganese Corporation of Birmingham, Ala. The deposit is on the upper northwest slope of a prominent ridge, part of a belt of red hills called the Fork Creek Knobs. It is at the unconformable contact of the Tellico sandstone on the Holston marble, the structure being monoclinal, the rocks dipping about 30° SE into the ridge. The Holston marble on the steep western slope is overlain by red sandstone of the Tellico. The crest of the ridge is composed of gray sandy marble in the Tellico.

At the time of visit no openings had been made, but there were ample indications of high-grade, red-hematite iron ore on the western slope just below the base of the Tellico sandstone, and with it a little manganese float. A large mass, 1½ feet across, of high-grade psilomelane ore was found on the east crest of the ridge, associated with the marble interbedded in the Tellico sandstone. The small amount of manganese-ore float on the western slope was not encouraging, but the high character of the ore and the generally favorable conditions for ore accumulation warrant prospecting to determine the quantity of the ore. It has been recently reported that such prospecting has been done by the Southern Manganese Corporation since the writers' visit, and only 3 tons of ore analyzing 41% manganese were taken out during the exploration, so that the property was abandoned.

Kimbrough Prospect.—The Kimbrough prospect is reported to be 4 miles northeast of Madisonville, and about 1 mile southeast of Fagan station, on the Louisville and Nashville Railroad. Although it is strictly not in the Fork Creek Knobs district, it will be here described for convenience, as there are no other prospects to be described with it under the Madisonville District, where it belongs.

Iron ore was mined here years ago, and it has recently been prospected for manganese, high-grade ore having been reported. The mine was not visited by the writers. It is apparently in chert and clay

residual from Knox dolomite close to its contact with the underlying Nolichucky shale. The Southern Manganese Corporation recently leased the property with the intention of developing it as an iron mine. It is reported to have found very little manganese ore and, although the quantity of iron ore seemed large, it has abandoned its lease.

TELLICO PLAINS DISTRICT.

The Tellico Plains district, in the southwestern part of the county, embraces the flat valley from Tellico Plains to the Red Knobs on the west and to Starrs Mountain on the southwest. The Ervin prospect just within the Red Knobs region will be included under this district for convenience in description.

Ervin Prospect.—The Ervin prospect is in the southwestern part of the county, 4½ miles northwest of Tellico Plains and 1½ miles south of Mt. Vernon on the Tellico Branch of the Louisville & Nashville Railroad. It is on the farm of Carrol Ervin, of Tellico Plains, and is being prospected by the Southern Manganese Corporation of Birmingham, Ala.

It is on a low terrace on the northwest slope of a prominent ridge of the Red Knobs close to Shoal Creek. It is in the Tellico sandstone, near its contact with a gray fossiliferous marble, probably Holston. The structure is a small syncline on the side of a larger syncline, probably faulted within.

The principal opening is a transverse cut running 75 feet northwestward across the rock structure, and having a depth of 10 feet. Two smaller cuts are lower on the slope. The ore is chiefly thin shells of siliceous iron with some psilomelane and a little manganite. The iron is largely in a solid ledge or crust, but the manganese ore is a wash ore in clay. The surface of the terrace to the northeast is literally covered with the siliceous iron ore crusts which seem to be a partial replacement of sandstone beds.

The hill is capped with sandstone fragments and iron crusts. Thin, buff to green shale which crops below, dips 30° SE on the northwest side of the syncline and strikes N 60° E and dips 75° NW on the southeast side. Beneath the shale on the northwest side is fossiliferous blue to gray, crystalline limestone or marble, probably Holston, dipping 30° SE. The limestone was not observed on the southeast side and may be cut off by a fault, which would account for the large quantity of si-

liceous iron ore on that side of the hill top. The syncline plunges northeast.

The iron ore is too siliceous to be a workable deposit, and the amount of manganese ore showing is too small to be of commercial value.

A similar deposit of brown-iron ore and a little manganese is reported on W. J. Cardin's property southwest of the Irvin property. It is on a small hill adjacent to the Red Knobs and lies in the shale overlying marble. An old cut mined for iron is on the property, but the showing of manganese ore is very small.

Groundhog Mountain Prospect.—The Groundhog Mountain prospect is 3 miles southwest of Tellico Plains on the northwest slope of Groundhog Mountain. It is on the farm of J. H. Curd, of Tellico Plains, and was opened some time ago for manganese.

Groundhog Mountain is composed of scolithus-bearing white quartzite, believed to be Hesse quartzite, with coarse dark-gray glistering dolomite, believed to be Shady, which is brecciated and largely changed to chert on the northwest upper slope. On the lower slope are shales which dip southeast into the mountain and overlie Chickamauga limestone at the road and are therefore probably Athens. The Hesse quartzite and Shady dolomite are apparently overthrust on the Athens shale, and the dolomite is both silicified and mineralized. The lowland is strewn with fragments derived from the mountain, consisting of scolithus-bearing white and red sandstone and pitted chert with drusy cavities.

The principal opening is an old cut 25 feet long and 15 feet deep at the face, midway on the northwest slope, 1,130 feet in elevation. The ore is in part embedded in dull-yellowish clay and in part replaces a dolomite and chert ledge. The ore is mostly nodular psilomelane, with a little manganite and soft crytalline pyrolusite. Some of it shows crude concentric platy replacement, and is siliceous. Smaller old pits are on the slope above and below the main opening. Those below, however, seem to have only float ore and show only a few small pieces of manganese-bearing chert similar to that at the main opening. Along the crest of the ridge on the quartzite, iron ore was extensively mined during the Civil War.

The manganese ore appears to be of good grade, but the quantity seems to be small. More prospecting along the line of outcrop of the replacement zone is desirable.

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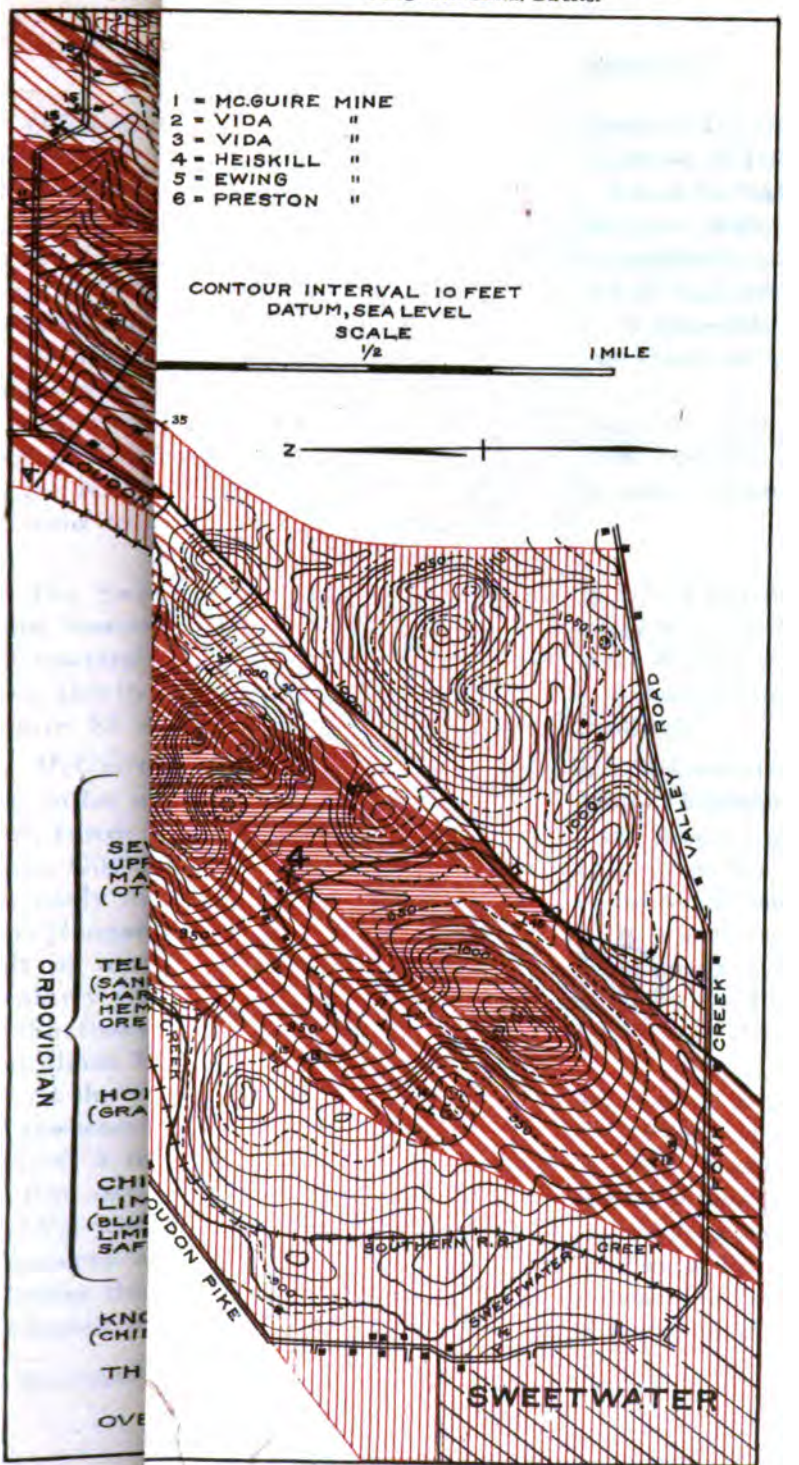
UNITED STATES GEOLOGICAL SURVEY
George Otis Smith, Director



F SWEETWATER, TENN., SHOWING
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Other Prospects Southwest of Groundhog Mountain.[1]—The Beaty prospect is southeast of Jalapa, about 3½ miles southwest of Tellico Plains and just southwest of Groundhog Mountain. It is on the land of N. H. Beaty. On a small knoll underlain by variegated shale, believed to be the Watauga, manganese ore occurs in considerable quantities as float ore in the soil. The ore is hard and of high specific gravity, and is probably good grade psilomelane. It apparently replaces the shale. It is said that large pieces of manganese ore were obtained from a pit on the property.

Other manganese and iron ore prospects are reported along the belt of low hills southwest of Groundhog Mountain, especially one on the Kilby farm, 4 miles southwest, where the manganese indications are said to be favorable.

SWEETWATER DISTRICT.

The Sweetwater District includes the ore-bearing belt of Red Hills from Sweetwater to Philadelphia, east of the Southern Railroad, and the lowland on either side. One deposit in the district, Hansard prospect, lies in the adjoining McMinn County, and will be described there. Figure 12 is a geologic map of the Red Hills mineral belt.

McGuire Mine.—The McGuire mine is on J. Frank McGuire's farm, 3½ miles northeast of Sweetwater and 3 miles south of Philadelphia, both towns being on the Southern Railway. The mine is only 1 mile from Gilman switch on the railroad. Ore was first mined here in the early nineties. The present mine is being operated by the Southern Manganese Corporation of Birmingham, Ala. It is in the same belt of mineralization as the Heiskell mine near Sweetwater and is similarly situated on the lower northwestern slope of the low Red Hills, at the frontal edge of a westward facing terrace 950 feet in altitude and about 100 feet above the valley bottom.

At the time of visit the main development, which consisted in part of reopened old workings, extended to the depth of 35 feet and had yielded 3 tons of high-grade ore which lay on the dump. A carload of this ore shipped since the writers' visit is reported to have run 41.13% manganese. The ore consists of psilomelane chiefly in slabby fragments and is mined in masses about 2½ feet in length by 5 or 6 inches thick. The deposit is at the unconformable contact of Tellico sandstone on the underlying Holston marble. The ore occurs chiefly

[1]Description is largely from notes by Arthur C. McFarlan.

in depressions and solution channels in the surface of the marble, filled with weathered products of the overlying formation. The structure of the rocks is monoclinal, the dip being approximately 25° SE.

The largest opening is a 40-foot cut made in the front of the terrace, at the south end of the property. It followed an old tunnel which ran southeastward in the clay filling a depression between rock pinnacles. The open cut has a depth of 20 feet at its face. Its northwest, or footwall, side consists of granular, grayish Holston marble capped by sandy-banded marble of the Tellico. On the southeast, or hanging-wall, side 10 feet of yellowish-red clay grades downward into 10 feet of reddish-black clay, both of which are somewhat ore bearing. The marble is banded, medium to coarse grained, and fossiliferous, containing abundant remains of crinoid stems, bryozoa, and a few brachiopod shells. Small lenses of ore occur in the sandy marble of the Tellico, and tabular pieces 6 inches thick, and rounded boulder-like masses ranging up to 2½ feet in diameter, are scattered in the residual clay which fills fissures and fractures enlarged to solution channels in the marble. The ore is mostly hard massive bluish psilomelane containing a cleavable crystalline mineral believed to be braunite, similar to that at the Heiskell mine, the identity of this mineral, however, not being certainly established.

A shaft on the terrace about 30 feet east of the face of the cut was sunk in residual clay and is reported to have struck a 3-foot bed of manganese ore at a depth of 23½ feet, and another shaft about 50 feet farther east passed through a bed of ore 7 inches in thickness at a depth of 33 feet. The ore in the shafts is similar in composition to that in the open cut but is softer, and is believed to be the same body of ore dipping southeast with the bedding.

As seen on a visit in October, 1918, a tunnel is driven into the face of the open cut and the mine is opened by a main inclined tunnel 165 feet long with lateral drifts to both sides 60 to 100 feet long, connected by other inclined longitudinal drifts. The workings follow a bed of ore more or less continuous near the bottom of the decomposed rock, which is the sandy ferruginous Tellico. The floor, where unweathered, is apparently Holston marble, but the ore in places lies within the decomposed sandy rock. It appears that the Tellico is in general decomposed to a soft mass of dirty brown sand to a depth of about 40 feet over this part of the terrace surface, the bedding being preserved in most places in the decomposed rock, undisturbed and

parallel to the bedding in the bedrock. In places the decomposition is much deeper than elsewhere and the bedding in the disintegrated material is much disturbed, the material being cut by many steep slickened planes, indicating that it has moved or settled down, probably into a solution channel in the underlying marble. The ore which is believed to have been originally disseminated in these sandy beds was dissolved by the descending water which decomposed the rock and was concentrated in the lowest porous beds through which it could flow. Where a boss of undecomposed rock stands as a pinnacle the ore is thin or absent. Where a cave-in occurred and the decomposed material fills a solution pocket or channel, the ore is apparently thicker and more continuous. The ore bed varies from 6 to 18 inches in thickness and from solid shiny psilomelane to sooty black ore. The dirt removed in the workings is said to run 5% manganese and 33% iron, the rest being largely quartz. The mine is reported to be shipping 40 tons of ore a month, averaging 44% manganese.

At the north end of the property many deep circular shafts or "wells" have been sunk. Most of these are on the flat top of the hill, 950 feet in altitude, and are sunk in soft residual sandy red clay between high steep-walled pinnacles of marble. These pinnacles are subsurface erosion forms and many of their walls are vertical and even overhanging, one well following such a vertical solution wall 30 feet in depth. The rocks dip 22° SE. The sandy beds of the Tellico, which disintegrate into the red sandy clay in which the ore occurs, out-crop at the west crest of the hill. Some yellow shale present in the pits is believed to have been let down in these solution pockets and not to be interbedded in the marble in place. The ore is reported to lie on the marble below the shale. Although the ore is of fairly high grade, much of it is deeply pitted and breaks into small fragments or crumbles to a soft powder, so that mining will be expensive if not impracticable. Several tons of such ore were on the ground at the time of visit, but mining had ceased. Other pits on the lower western slope of the hill, 920 feet in altitude, are in similar soil-filled depressions in the marble, and although excellent psilomelane ore was taken out, the quantity is relatively small.

Preston Prospect.[1]—The Preston prospect is 3½ miles northeast of Sweetwater, near the Loudon pike. It is on the west slope of a low ridge just west of the McGuire mine, on the farm of J. N. Preston, of

[1]Description chiefly from notes by Arthur C. McFarlan.

Sweetwater, and is being prospected under option by Joe Corn. The low rounded ridge is composed of Chickamauga limestone, which dips 12° SE, the structure being monoclinal. The showings consist in part of float ore in the form of nodular pieces of psilomelane scattered in considerable quantities along the crest and western slope of the ridge for more than half a mile. With the manganese ore is also a large amount of good hematite float. About 1½ tons of iron and manganese have been gathered in piles, and several tons of high-grade ore were sold to the Southern Manganese Corporation.

Some of the psilomelane replaces chert, and the occurrence of a few pieces of leached Tellico sandstone in the soil suggests that the ore may have been derived from the rocks on the ridge to the east where the McGuire mine is located, having been worn away and transported by hillside wash before the small intervening valley was eroded.

Vida Mine.—The Vida mine is 3 miles northeast of Sweetwater. about a half mile southeast of Gilman siding on the Southern Railroad. It is owned by C. D. Smith, of Memphis, Tenn. It was mined for iron several years ago by W. D. Gilman and is described by E. F. Burchard in Bulletin No. 16 of the Tennessee Geological Survey on the Red iron ores of East Tennessee. The ore was taken from two large pits, a half mile apart, 20 to 30 feet deep, in soft dirty, red, dry, sandy clay. The ore was largely soft, but many fragments of harder ore are still scattered over the ground. These are largely blocky to platy fragments of dark iron ore, somewhat earthy and apparently containing considerable manganese. Lumps of good bright psilomelane having rounded shiny surfaces are also rather plentiful. Although the pits are underlain by Chickamauga (Lenoir) limestone or Holston marble, the ore lies in yellow shale or clay and earthy red sandy clay with steep bedding, believed to be the decomposed overlying Tellico let down in a solution cavern in the marble. East of the pits highly ferruginous sandy marble of the Tellico outcrops, which is believed to be the rock which was the source of the ore. Thin leaves of bright hematite lie along joints and bedding planes in the marble. Much of the surrounding territory appears to be equally favorable for manganese ore and there may be a sufficient quantity to be worked, for this ore carries 43 to 46% manganese. No effort has been made recently to mine the property.

Ewing Mine.—The Ewing mine is ½ mile south of the Vida mine and about ½ mile from Gilman siding on the Southern Railroad. The

property is owned by Robert Ewing, and was worked for soft iron up to June, 1918, by J. J. Fitzgerald and H. L. Smith, of Sweetwater. The mine is on the Holston marble near the contact with the Tellico sandstone. Considerable manganese ore is also present, and the mine may be workable for manganese. It was closed down and was not visited by the writers.

Heiskell Mine.—The Heiskell mine is in the northwestern part of the county, 1 mile northeast of Sweetwater. The land is owned by Harry Heiskell, of Sweetwater, and the mine was being operated by H. L. Smith, also of Sweetwater, on an option to buy the mineral rights. It is on a hillside which slopes gently northwestward to Sweetwater Creek. The soil of the hill, which is about 950 feet in altitude, is deep red, and the hills are therefore called the Red Hills. The ore is all lump ore and is shipped without washing. The inclosing clay is dry and pulverulent and is removed in handling. Therefore no plant is required, and the cost of mining is very low. The mine is credited with a production of more than a hundred tons of high-grade manganese ore. At the time of visit (April 25) a carload of ore had recently been shipped, and about 40 tons lay on the dump. The ore is said to run 58% manganese.

The ore is unusually pure, solid, compact psilomelane and occurs chiefly in thick blocky pieces, some a foot or more across, embedded in residual red sandy clay. The blocks have irregular or pitted surfaces. The mineral breaks with a conchoidal fracture and a freshly broken or polished surface presents a poikilitic or mottled effect due to cleavage faces of included crystals of manganite and braunite. The latter mineral is not certainly identified, but some of its characteristics have been observed. Associated with the manganese ore are fragments of very pure red hematite. The deposit has been opened by 4 pits covering a length of about a thousand feet. Two of the openings are on the hillside, and two on the lowland at the foot of the hill.

The northern opening, which is on the upper part of the hillside, shows the original relation of the ore. The deposit is at the contact of the Holston marble and the unconformably overlying Tellico sandstone. The ore lies in dark-reddish sandy clay which fills deep solution hollows in the upper surface of the marble. This deep weathering occurred when the flat top of the hill, now 950 feet in altitude, was part of the floor of the valley. The rocks dip 22° SE, and coarse red sandy granular marble beds of the Tellico sandstone cap the Hol-

ston marble at the top of the hill. Iron and manganese oxides were deposited in the pores and small crevices of this capping rock, which is called the hanging wall of the deposit, as the lime was dissolved out, and it probably now carries an average of 3 to 5% of manganese and a larger amount of iron. The red sandy clay, in which the pit is dug, is the residuum of similar beds of Tellico sandstone which formerly overlay the Holston marble.

The manganese and iron oxide ores were concentrated into beds and lenses of ore in favorable places in the Tellico sandstone by solution and redeposition in the process of weathering, and have been broken up and left as residual masses in the residual sandy clay. Some of the ore preserves molds of the fossils in the original rock, showing gradual replacement. From a small excavation, at no point more than 6 feet in depth, 33 tons of large hand-picked blocky psilomelane ore, probably averaging 58% in manganese, had been mined. At the time of visit this ore was still on the ground, and its immediate shipment was urged by the writers. One carload shipped from this upper hole was reported to have run only 52% manganese and carried from 2 to 3% iron, but this was not a representative analysis.

At the south end of the property on top of another low hill close to the road iron ore was formerly mined in a pit similarly located at the Tellico-Holston contact. No ore has been taken out recently, although good hematite and some manganese ore still show in the pit.

The pit that was being actively worked at the time of visit lay at the south foot of the hill on which the north opening occurs. The pit was 18 feet deep in dull dark-reddish sandy clay, largely residuum of Tellico sandstone which had moved down the slope by creep and hillside wash and accumulated at its foot. Fragments of porous fossiliferous sandstone from the Tellico, and of ore derived from the deposit above, were sporadically distributed in the clay, the fragments of ore being much smaller than those in the upper pit and more widely scattered. They extended, however, to the bottom of the pit. The mining methods at present employed are wasteful and considerable ore is believed to have been left in the ground and covered with waste from the mine.

The northeastern opening is also in the lowland at the foot of the hill. This pit is 10 feet deep in sandy, red clay wash from the

hillside. The ore is chiefly hematite, but some good psilomelane has been taken out. About 8 tons of fair grade manganese ore lay on the dump.

Manganese ore is reported on the Red Hills northeast of the Heiskell mine, but no prospects were opened so far as known. All the land between the Heiskell and McGuire mines has favorable geologic and surface conditions for the occurrence of high-grade manganese and iron ores and should be thoroughly prospected. These geologic conditions do not continue southwest of the Heiskell mine, so search in that direction will be fruitless.

Dickey Prospect.—The Dickey prospect is 1½ miles north-northwest of Sweetwater on the farm of A. J. Dickey. It is on the top of Black Oak Ridge, a chert ridge in the Knox dolomite. About 20 years ago George Loring and James Schell, of Sweetwater, opened up the deposit and, according to reports, shipped 2 carloads of good manganese ore. The property has since been idle.

McDonald Prospect.—The McDonald prospect is 4 miles southeast of Sweetwater and about that distance from the Southern Railway. It is on the McDonald farm in the lowland near the head of Fork Creek. Prospecting was being done by the Southern Manganese Corporation of Birmingham, Ala., which had acquired a lease of the mineral rights.

The prospect is located on the northwest side of a low hill about 50 feet above Fork Creek. It is in residual clay and chert of the Knox dolomite, the ore replacing the chert. The overburden consists of about 4 to 5 feet of red clay and chert fragments.

The opening is a pit 10 feet across and 15 feet deep, which exposes about 5 feet of red surficial clay overlying yellowish residual clay in which is a little ore, especially at its top where 1½ feet of darker clay contains some ore in blackish blotches, streaks, and disseminations. The ore is psilomelane, inclosing small angular fragments of chert which give it the appearance of a breccia. About 400 pounds of ore were on the dump. It was said to average 43% manganese, but this has reference to the ore free from silica and not as it runs, which will be much lower. The small amount of ore from the pit and the little float on the surface were regarded unfavorable.

McMinn County.

McMinn County, of which Athens is the county seat, lies directly west of Monroe County. It is largely a lowland or valley crossed by many low straight ridges which trend northeastward. Manganese deposits are reported at four localities, the Hansard prospect in the Sweetwater district, the Patton and associated prospects in the McMinn Ridge district, the Gilbert prospect in the Athens district, and the Bishop and associated prospects in the Charleston district. The Underwood mine, also in the Charleston district, is in Bradley County.

SWEETWATER DISTRICT—(CONTINUED.)

Hansard Prospect.—The Hansard prospect is near the eastern border of the county, 3 miles west of Sweetwater and therefore in the Sweetwater district. It is on the farm of J. B. Hansard, of Sweetwater, the mineral rights of which are leased by the Southern Manganese Corporation of Birmingham, Ala.

The prospect occurs on the northwest edge of a chert ridge overlooking the valley of Pond Creek near its head. The ore replaces chert of the Knox dolomite and is found in scattered masses on the surface and in the soil. The ore mineral is good psilomelane, said to run 51% manganese, cementing brecciated chert and in part replacing it. A few masses of such ore 1 foot across containing much chert were found along the road. A small amount of ore embedded in yellow clay was recently dug from a well near the barn. On the northwestern slope of the ridge it had been prospected by several shallow pits which at the time of visit showed mostly iron ore. It was reported that from these pits and the surrounding fields about 600 pounds of ore averaging 52% manganese were recently shipped, but it is probable that the general run of ore will not average more than 40% manganese on account of the silica content. There appears, furthermore, to be very little ore present.

MC MINN RIDGE DISTRICT.

The McMinn Ridge district embraces the chert hills in the western part of the county, where manganese deposits have been reported.

Patton Prospect.[1]—The Patton prospect is 8 miles west of Riceville on the Southern Railroad, close to the western boundary of the county. It is on the farm of G. I. Pierce, of Riceville, 2 miles from the wagon road to Vigor and has been prospected by W. M. Patton, of Cleveland, who has an option on the mineral rights. The deposit is in the Knox dolomite, which is weathered to a very cherty soil.

It is opened by a pit 6 feet deep, which shows considerable psilomelane replacing chert. There is also a large amount of brown-iron ore present which makes up more than half the ore. The manganese ore is said to run 52% manganese, but the amount of chert present, which cannot be removed without an expensive plant, will make the ore analyze much lower.

Several new prospect pits recently sunk along the trend of the ridge from the old pit are reported to show a better grade of ore, and indicate that the ore follows a certain horizon in the rocks. But, like most deposits in the chert of the Knox dolomite, this prospect is not of much promise.

Manganese ore replacing chert is also found on the Henry Reed farm southwest of the Pierce property on the same chert ridge. Conditions are probably the same as at the Patton prospect.

ATHENS DISTRICT.

The Athens district embraces the portion of the Red Hills around Athens. They lie south, southeast, and northeast of the town. A few prospects are reported south of town.

Gilbert Prospect.—The Gilbert prospect is a mile southeast of Athens on the farm of I. W. Gilbert, just north of the Etowah pike. It is undeveloped, and consists of showings of ore in residual yellow clay soil of the Tellico sandstone, which here dips about 30° SE.

A small black streak of soft pyrolusite and wad is exposed in a wagon road on the property, and similar material shows at several places in a small creek near by, where it is continuously exposed for nearly 50 feet, apparently being a seam along the bedding. No hard manganese ore was seen, although good red hematite occurs on the ridge top.

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[1]The descriptions of the Patton, Bishop, and Gilbert prospects are largely from notes by Arthur C. McFarlan.

On the J. H. Jones farm, which joins the Gilbert farm on the east, float manganese ore and considerable iron ore occur. Some of the manganese was of good grade pyrolusite. This deposit is in the shale overlying the Tellico sandstone and mapped as Sevier shale on the Cleveland folio of the Geologic Atlas of the U. S. Geological Survey.

The showing at these prospects is very poor, and further prospecting does not seem warranted.

CHARLESTON DISTRICT.

The Charleston district embraces chiefly the area of Red Hills lying east of Charleston and Calhoun. They trend northeast, and begining as a small hill at Climer, east of Tasso, expand northeastward to a belt 2½ miles wide, and continue as such past Athens. Several prospects and a mine occur east of Charleston.

Bishop Prospect.—The Bishop prospect is in the southern part of the county near Hiwassee River, on the farm of J. M. Bishop. It is on one of the Red Hills which in this region make a belt 2½ miles wide. The deposit is apparently in the Holston marble near the contact of the overlying Tellico sandstone. The rocks are about horizontal, but in general dip slightly to the southeast. The Tellico is here a pronounced sandstone, not as calcareous as southwestward near Cleveland where some of the best deposits in this formation are being mined.

The deposit has not been opened by pits, the prospect consisting of nodules and fragments of high-grade psilomelane lying loose in red sandy clay exposed in the road. The nodules are small, but one piece 3 inches in diameter was found. The ore is similar to that being mined in the Red Hills district south of Cleveland, and although the showing is small, the immediate vicinity is well worth further prospecting.

A small amount of manganese and larger quantities of iron ore occur on the adjoining properties in the Red Hills, particularly on the farms of J. B. Liner, J. M. Lawson, and T. M. McKnight. Sandy iron ore and sandy psilomelane which occur generally on all the properties, is a replacement of the binder of the Tellico sandstone by ore. It is generally underlain by alternating yellow shale and sandstone near the base of the Tellico sandstone.

BRADLEY COUNTY.

Bradley County, southwest of McMinn County, from which it is separated by the Hiwassee River, is the southernmost county of the manganese belt. Cleveland, its county seat, is near its center. The country is crossed by many low ridges which trend northeast and give it a hilly appearance. The western boundary follows White Oak Mountain, a somewhat higher ridge standing out in the valley. The county contains a number of successful manganese mines and many prospects, most of which occur in the Holston marble, but two of which are in the Fort Payne chert.

CHARLESTON DISTRICT—(CONTINUED.)

Underwood Mine.—The Underwood mine is 3½ miles south-southeast of Charleston and 1 mile south of the Hiwassee River. It is on the farm of I. M. McAllister, but the deposit is also prospected on the adjoining farms of other members of the McAllister family and on Jack Thompson's farm. It was opened by W. B. Underwood and is now being operated by W. E. Hamilton & Company of Columbus, Ohio, W. B. Underwood manager, leased on a royalty basis. At the time of visit about a ton of rather low-grade manganese ore and several tons of iron ore lay on the dump. Later A. C. McFarlan reported 5 or 6 tons of psilomelane and iron ore on the dump.

The deposit occurs on the slope of a prominent red hill about 1,000 feet in elevation. The top of the hill is capped by Tellico sandstone which is underlain by thin yellow shale and light-gray marble, probably Holston. The structure is a minor synclinal with gentle dips.

The principal opening is a 70-foot cut on the northwest face of the hill 80 feet below the top. It runs northeastward along the hillside and has a width of 12 feet and a depth of 20 feet at the face. The manganese ore is chiefly psilomelane, occurring as loose fragments and chunks which range up to several hundred pounds in weight, and some wad, lying in dark-red clay with dark waddy sand streaks. Good hematite and some brown-iron ore are also present. Blocks of weathered red sandstone are also inclosed and the deposit is evidently an accumulation of wash from the hillside above. The irregular occurrence of the streaks of ore-bearing sandy clay, exposed in the trench and in a deep pit lower down on the slope, harmonize with

this view. The amount of ore is small compared with the material removed from the trench.

Higher up the hill, in a saddle between knobs, a circular pit 20 feet deep penetrates nearly barren yellow shale to firm gray marble at the bottom, lying about horizontal. A few thin seams and stringers of ore penetrate the marble. Another pit on the southeast side of the hill is in barren yellow shale. Soft red sandstone overlies the shale at the top of the hill. Float ore is reported along the crest of the hill to the northeast, and recent prospecting there is said to have been more favorable. The indications are sufficiently favorable to warrant further careful prospecting, as the presence of some good ore is established and the horizon is known to be highly ore-bearing in an adjacent belt to the southwest.

CLEVELAND DISTRICT.

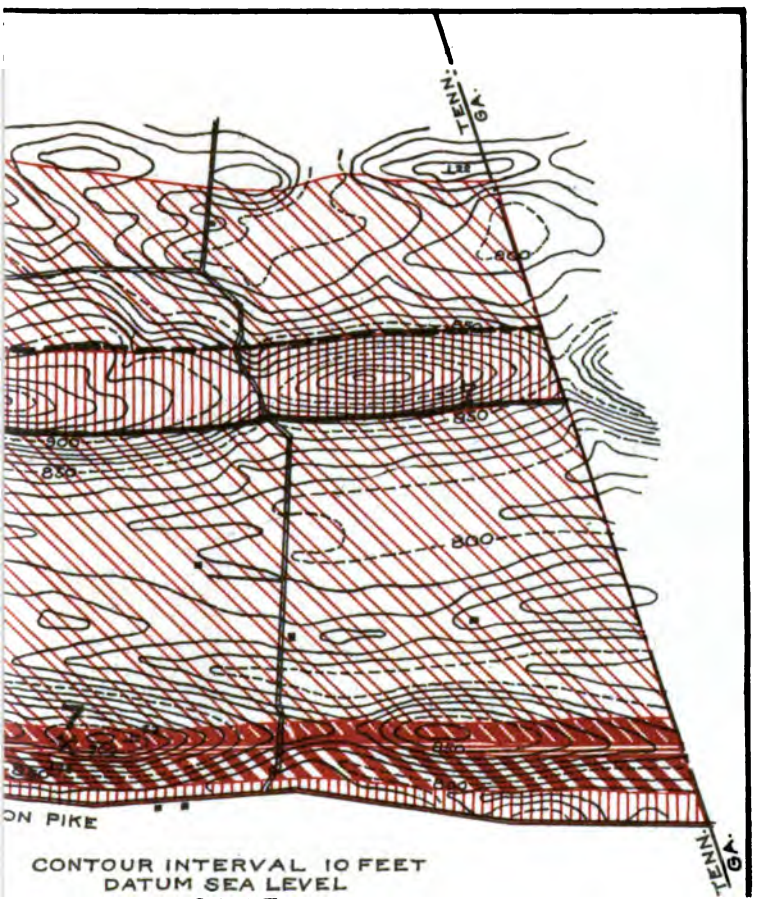
The Cleveland district embraces not only the vicinity of Cleveland, but the area of Red Hills 5 to 12 miles south of town to the State boundary, where some of the best deposits of manganese have been found. Figure 13 is a geologic map of the Red Hills mineral belt.

Hambright Mine.—The Hambright mine is 8 miles south of Cleveland and 2 miles east-northeast of Marble Switch, the nearest station on the Southern Railroad. It lies in the Red Hills east of the Cleveland-Dalton pike. It is owned by H. F. Hambright. of Cleveland, and is operated by Fitzgerald & Lanskey, of Chicago. The deposit occurs on the Holston marble at its contact with the overlying Tellico sandstone and is described in detail as one of the types of deposits in East Tennessee in Part I of this paper on pp. 184 to 189.

The mine has been recently equipped with six-wheeled scrapers which move the dirt more rapidly and economically. These are especially needed in the new development at the north, where a cross trench 60 feet wide is being cut across the ridge to give access to and to drain the deeper workings along the ore body. It is to be cut 40 feet deep. A steam shovel may be installed later.

The farm of Bird Hambright, north of the mine, also has some indications of ore. Good float manganese ore and red hematite occur at several places on the slopes of the Red Hills, but small prospect pits have thus far failed to strike the ore body, probably because they are not deep enough. The property is not at present leased for mining purposes, so far as known.

UNITED STATES GEOLOGICAL SURVEY
George Otis Smith, Director



Brandon-Nashville

UNIV. OF MICH.

Jones Prospect.—The Jones prospect is about three-fourths mile south of the Hambright mine and 2 miles east of Marble Switch on the Southern Railroad. It is in the open fields on the upper slope of the low red hill east of the road on M. V. Jones's farm. It is in Tellico sandstone at its unconformable contact with Holston marble. The structure is locally synclinal, the dips on the western slope being 35° SE, and on the top of the hill are about horizontal, but on the east slope are southeast again.

Within an area of about 300 feet in diameter on the top and upper western slope of the hill near the north end of the property the deposit has been prospected by pits and shafts to a maximum depth of 25 feet. They show only small amounts of soft manganese ore with pulverulent iron ore and black wad in deep-red clay. No amount of solid manganese ore was found. Near the south end of the property, just north of the Rock Quarry Gap road in the middle of the west slope, there are 6 or more pits from 6 to 20 feet deep in red sandy clay lying in hollows between marble pinnacles. One circular shaft exposes the irregular vertical wall of such a pinnacle to a depth of 20 feet. Fragments of high-grade hematite are abundant, but no manganese ore other than small traces of wad and pyrolusite were found. The marble is banded with dark highly ferruginous material and probably contains on the average at least 5% of iron. The marble and the thin overlying yellow shale, which here intervenes between the marble and red sandstone, are highly fossiliferous, containing chiefly bryozoa as at Sweetwater. Similar geologic and surface conditions are found south of the Rock Quarry road on the property of J. H. Jones. The mineral rights to both Jones properties are reported leased to the Tennessee Manganese Company, and, although the indications at present are not favorable for a good deposit of manganese ore, further search, probably to the southeast at greater depth down the contact zone, may be fruitful.

Sloan Prospect.—The Sloan prospect is about 1 mile south of the Jones prospect on the same line of Red Hills. It is 1½ miles southeast of Marble Switch on the Southern Railroad, close to Flint Springs. The property is owned by the Sloan heirs and is farmed by W. B. Sloan, one of the heirs. It was developed under option by E. C. O'Brien for the Seaboard Steel and Manganese Corporation, of Temple, Pa., and its purchase by that company was considered, but has not been consummated.

The prospect is at the north end of the low ridge on which the Lord and D. A. M. mines are located, at the west base of the hill on a level with the road and not over 200 feet from it. The deposit occurs in impure Holston marble, which is overlain by seamy calcareous Tellico sandstone. The structure is monoclinal, the rocks dipping 30° SE. The deposit is opened by a pit running into the hill 20 feet and about 25 feet deep at the face, exposing brown even-grained marble dipping 20° SE. At the top of the hill, 20 feet above, is soft ferruginous red sandstone of the Tellico. The ore is embedded in red sandy clay which fills large solution pockets in the marble. About 2 tons of high-grade hematite and good manganese ore, mostly in the form of slabs ½ to 1½ feet across, lie on the dump. Little ore was showing in the sides of the pit, but considerable float ore occurs in the soil of the fields on the hill back, and to the southeast of, the pit. This has been slightly tested by auger borings, but should be thoroughly prospected by pits to determine the direction of the Holston-Tellico contact, which is the zone of most concentrated ore. Although not enough prospecting has been done to prove up the property, it is believed to have large possibilities and should be developed by some responsible company.

D. A. M. Mine.—The D. A. M. (abbreviation for Davis, Artz, and McCrossin, the owners) mine is nearly 2 miles southeast of Marble Switch on the Southern Railroad, and not one-half mile south of the Sloan prospect. It was the first mine in the district to be opened and is reported to have early shipped about 300 tons of 50% manganese ore and more recently to have shipped 50 tons. The recent shipment is said to have averaged 53% manganese. The mine has been operated by Davis, Artz, and McCrossin, of Cleveland, but was idle when visited. It was reported that it had been sold early in 1918 and that its operation would be resumed soon.

The mine is located on the same low terraced ridge as the Lord mine, which adjoins it on the south. The workings are extensive and lie in a belt 200 feet wide trending north-northeast, which has been opened by pits for a length of 500 feet. The workings are mostly open cuts in the upper southeast slope of the ridge which follow solution crevices at the contact of the Tellico sandstone and the Holston marble, going down with the dip of the rock at an angle of about 25° SE. Most of the workings are shallow, but at the north end of the property a 30-foot shaft descends from the bottom of a 15-foot pit.

It followed a mass of sandy clay filling a vertical solution crevice between firm fresh siliceous marble on the southeast and decomposed marble on the northwest, both strongly marked with impure ferruginous laminae like the Tellico. Thin seams of hematite and a little manganese ore still occur along the bedding planes of the marble walls down to the bottom, and ore probably occurred throughout the clay in the pocket. The shaft is reported to have passed through an 18-inch bed of ore at a depth of 32 feet, probably at the base of the Tellico. The manganese ore is a high-grade massive psilomelane, and the iron ore a pure red hematite, the latter preserving excellent impressions of fossils which were replaced in the marble.

The deposit is thus seen to occur in the Tellico sandstone at its contact with the underlying Holston marble, which is unconformable in most places. The structure is monoclinal, the dip of the marble being 25° ESE at the north end to 50° ESE at the south end of the property. The overburden is in general about 2 to 8 feet of dark-red residual soil and sandy clay, and is much deeper in solution pockets and channels. The ore solutions seem to have been derived from the disintegration of beds in the lower part of the Tellico sandstone, and to have descended through the disintegrated rock at the surface into solution channels. The basal beds of the Tellico seem to be the most easily percolated, and solution channels are most plentiful at the base of the sandy beds. The ore was deposited both in the channels and in small crevices along the bedding and joints in the wall rock of the channel. A solid layer of ore at the contact of the marble and sandstone, such as has been described at the Hambright mine, was not observed here, but may have been encountered in the shaft. It is probable that the larger masses of ore in pockets have been mined out in the open pits, but there is every reason to believe that other workable pockets of high-grade ore are still in the ground in the unworked spaces between the pits, and down the dip below the present workings. The latter will have to be worked largely by inclined shafts and tunnels.

Lord Mine.—The Lord mine adjoins the D. A. M. mine on the south and is 10 miles south of Cleveland and 1½ miles east of Weatherly Switch on the Southern Railroad. It is on the Boyd farm, the mineral rights being owned by the C. H. Lord Corporation of Chicago, Ill., and is being operated by the Tennessee Manganese Company of Cleveland, Tenn., under lease. It is credited with a produc-

tion in 1917 of 650 tons and in the first half of 1918 with 1,500 tons of high-grade ore, said to have averaged 58 to 60% manganese.

The mine is on the low broad-topped red hill on which the D. A. M. mine is located which, together with the other low red hills of this valley, are remnants of an old valley floor which now stands at 950 feet altitude. Round river cobble of quartzite occur on the tops of several of the ridges, indicating that some large stream once had its channel in this valley on this old valley floor. The deposit occurs in the Tellico sandstone at its unconformable contact with underlying Holston marble. The structure is monoclinal with the strike of the rocks N 30° E and the dip 40° SE. The disintegrated sandstone carrying the ore fills pockets and solution channels in the upper surface of the marble, some of which follow down the dip of the rocks.

The deposit is opened by an east-west pit 300 feet long by 100 feet in width in the side of the hill. At its face, in the highest part of the hill, the pit has a maximum depth of 50 feet. The excavation is chiefly in dark-red sandy clay with yellow clay bands and patches, but exposes unweathered marble at several place in the bottom. The face and eastern part of the pit are in dark-red sand with thin yellow clay bands dipping 40° SE, which preserve all the features of the sandy marble of the Tellico with thin yellow calcareous-shale streaks from which it was derived by decomposition, the calcareous matter having been entirely removed. The unaltered marble ribbed with ferruginous, siliceous banding, somewhat cross-bedded and lenticular, is exposed in depth. Thin lenses and stringers of hematite are deposited along the bedding and joint planes. Along the contact of the siliceous marble and the purer marble is a layer of nearly pure manganese ore, 6 inches to 2 feet thick, which had been exposed along a solution channel down the dip below the bottom of the pit, and is regarded as the main body of ore and the source of much of the lump ore in the sandy clay in the western part of the pit. It seems to be continuous across the whole width of the pit for 40 feet along the strike.

To the west of the sandstone-marble contact the red sandy clay is not regularly bedded, but is banded in various directions and contains masses of yellow clay resembling a coarse breccia. The sandy clay has many slickened planes, coated with bright-red clay. The material was evidently derived from the disintegration of Tellico sandstone which formerly covered the marble and was let down on the irregular sur-

face of the Holston marble pitted by solution under cover. Rounded bosses of fresh marble exposed at the bottom of the pit 5 or more feet high are covered with a layer 6 to 10 inches thick of pulverulent clay soil in which most of the loose ore fragments occur, and this is generally covered with a thin layer of bright-yellow barren clay separating it from the overlying, soft, dark-reddish sandy clay derived from the Tellico sandstone. Figure 14 is a rough sketch of the conditions in the pit when visited.

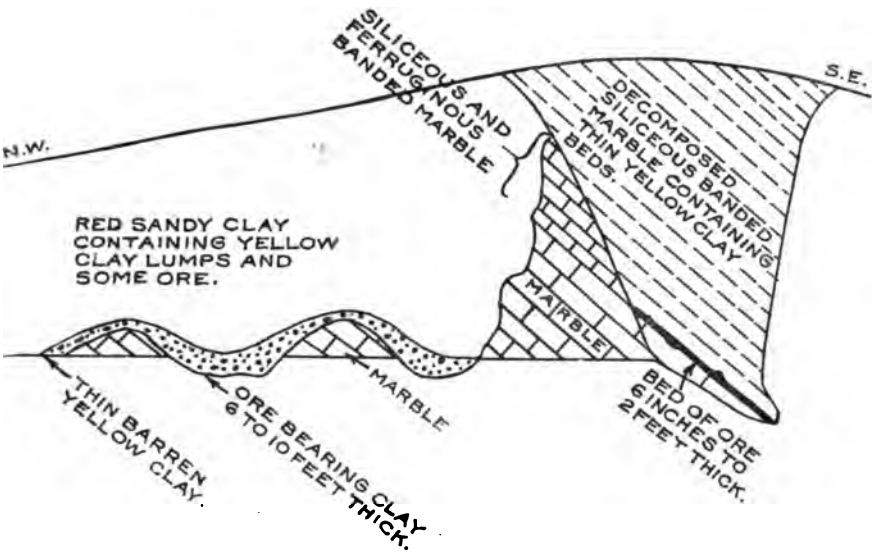

N.W.
S.E.
SILICEOUS AND FERRUGINOUS BANDED MARBLE
DECOMPOSED SILICEOUS BANDED MARBLE CONTAINING THIN YELLOW CLAY BEDS.
RED SANDY CLAY CONTAINING YELLOW CLAY LUMPS AND SOME ORE.
MARBLE
MARBLE
THIN BARREN YELLOW CLAY.
ORE BEARING CLAY 6 TO 10 FEET THICK.
BED OF ORE 6 INCHES TO 2 FEET THICK.

Figure 14. Sketch section across pit of the Lord mine, showing ore layer in place and relation of ore-bearing clay to the bedrock and to the red sandy clay. Scale, *about* 1 *inch*=30 *feet.*

About 50 feet east of the face of the main pit a vertical double-compartment shaft was started on the east slope 15 feet below the top of the ridge to reach the main bed of ore and mine it by drifting. It passed through 10 feet of red clay at the surface, then 32 feet of yellow clay, and at the time of visit had passed into soft black waddy earthy sand. It has recently been reported to be down 60 feet, the bottom in Holston marble, and to have struck the ore bed which improved with depth.

The ore is chiefly massive hard psilomelane, but includes also a little soft ore consisting of pyrolusite and wad. Some of the ore

contains a small amount of white wavellite with a radial fibrous structure. The ore is all lump ore and is shipped without washing. Overlying the manganese ore in the western part of the mine is considerable soft, pulverulent red hematite, greasy to the feel. The mine was equipped with an expensive derrick-like apparatus about 60 feet long with cable and bucket, but it was found unsuited for the work. A drag line scraper was being used at the time of visit, but it is reported that the mine has recently been equipped with an automatic loader and dumper type of scraper with a bucket capacity of 1½ cubic yards.

An old tunnel goes into the hill from the valley east of the mine, but it did not reach the ore. Two small prospects have been recently opened on a small knoll across the valley from the mine about 500 feet to the east. They are trenches about 6 feet deep in red clay and strike a little wad and some hematite, but very little hard manganese ore. The deposit is on a marble bed associated with yellow Sevier shale (Ottosee) higher than the ore bed at the mine.

Snyder Prospect.[1]—The Snyder prospect is just south of the Lord mine, a mile and a half from Weatherly Switch on the Southern Railroad. It is on the Snyder farm and is undeveloped. A short-time option on the property is held by the Tennessee Manganese Company.

It is on the east slope of Red Ridge, in Tellico sandstone near its eastern contact with Knox dolomite along a thrust fault. The chert of the Knox dolomite forms a prominent ridge with white soil just east of the fault. The Knox is thrust against red sandstone of the Tellico dipping steeply southeast, apparently on the east limb of an overturned syncline which incloses Sevier shale in the middle.

The best mineral showing consists of good float ore along the base of the chert ridge close to the fault. The ore is fairly abundant and consists chiefly of high-grade psilomelane very similar to that of the Lord mine. The surface indications are regarded as favorable for finding a workable ore deposit, and prospecting is recommended.

Hannah Prospect.—The Hannah prospect is 1¼ miles south of the Lord mine and about 2 miles by road from Weatherly Switch on the Southern Railroad. It is on Mrs. Hannah's farm and has been

[1]The descriptions of the Snyder, Gee, and Brown prospects are largely from notes by Arthur C. McFarlan.

prospected by the Tennessee Manganese Company, which has a lease on the mineral rights. It is reported to have produced 8 tons of ore from clay close to the limestone floor beneath several feet of residual red sandy clay. The deposit is in Tellico sandstone overlying Holston marble.

The prospect, now caved, is located in the west slope of a Red Hill south of the hill on which is the Lord mine. The trench is 10 feet deep in residual red sandy clay resting on siliceous banded marble containing yellow shale bands which dip 45° SE. On the slope below the pit coarse crystalline marble is underlain by white and blue limestone of the Chickamauga. No ore was seen in the walls because of slumping.

Gee Prospect.—The Gee prospect is 10 miles south-southwest of Cleveland, just west of the Cleveland-Dalton pike and about a half mile west of the Lord mine, on the farm of Burley Gee. It is on the crest of a chert ridge in the Knox dolomite, and except for a small prospect pit is undeveloped.

The ore is psilomelane filling fractures and cementing, and in part replacing, fragments of chert. It occurs in considerable amount scattered over the surface and embedded in the residual clay. Similar showings are said to occur also on the neighboring Davis farm. Such deposits, however, have very deceptive surface showings and can only be proved up by prospecting.

WHITE OAK MOUNTAIN DISTRICT.

White Oak Mountain lies 7 miles northwest of Cleveland, its crest being the western boundary of the county. It begins north of the latitude of Cleveland and runs southwest to the State line. Manganese ore is reported in the mountains from several places west of Cleveland.

White Oak Mountain Mine.—The White Oak Mountain mine is near the west boundary of the county 7 to 8 miles northwest of Cleveland. It is owned and operated by the White Oak Manganese Corporation of Cleveland, and has produced about 40 tons of manganese ore and about 1,000 tons of manganiferous-iron ore which lie on the dump at the mine, no shipment having been reported. The mine is on the crest and upper east slope of White Oak Mountain, at elevations ranging from 950 to 1,100 feet. The deposit occurs in the Fort Payne chert. The mine is described in detail as one of the types of manganese deposits in Part I of this paper, pages 189 to 190.

Brown Prospect.—The Brown prospect is 3 miles northwest of McDonald station on the Southern Railroad, in White Oak Mountain. It is on the farm of Jake M. Brown on a hill 200 feet above the valley bottom. It is underlain by Fort Payne chert, and the relations are similar to those at the White Oak Mountain mine 6 miles northeast.

The property is undeveloped. The ore indications are abundant float ore in places, composed of psilomelane cementing fragments of chert and partly replacing it. The ore fragments in the soil are filled with chert and are too siliceous to be shipped without crushing and separating the chert. At one place a thin seam, not over 1 inch thick, of psilomelane, accompanied on either side by about a foot of soft decomposed manganiferous and ferruginous rock was observed. The indications are not regarded as favorable.

A similar manganiferous-iron ore deposit was exposed in a small pit on the crest of the mountain on James Wolf's farm, 2 miles west of McDonald.

PRODUCTION OF MANGANESE ORES IN TENNESSEE.[1]

	35% Mn. and Over.	10 to 35% Mn.
1886 to 1914	2,680 (approx.)	....
1915	250	....
1916	529	....
1917	2,294	83
1918—		
1st quarter	451	231
2nd quarter	389	728
3rd quarter	1,536	839

The production of manganese ore and ferruginous manganese ore in Tennessee for the last four years is shown in detail in the above table. On account of the delay in publishing this issue of "The Resources of Tennessee," it was possible to procure the production figures for the third quarter of 1918. In the first nine months of 1918, more manganese ore was mined than during 1917.

[1]From U. S. Geological Survey records.

MAR 15 1919

VOLUME IX NUMBER 1

THE RESOURCES OF TENNESSEE

A MAGAZINE DEVOTED TO THE DESCRIPTION, CONSERVATION AND DEVELOPMENT OF THE RESOURCES OF TENNESSEE

PUBLISHED
JANUARY, APRIL, JULY AND OCTOBER
BY THE
STATE GEOLOGICAL SURVEY
NASHVILLE, TENN.

JANUARY, 1919

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List of Publications.

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VOLUME IX NUMBER 1

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Published by the State Geological Survey
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JANUARY, 1919

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LETTERS OF TRANSMITTAL

NASHVILLE, TENN., January 16, 1919.

To His Excellency, the Governor, and Members of the Geological Commission:

GENTLEMEN—In compliance with the law establishing the State Geological Survey, I have the honor to transmit the report of the State Geologist for the biennial term ending December 19, 1918.

The Survey was under the direction of Dr. A. H. Purdue until his death on December 12, 1917. Dr. L. C. Glenn was acting geologist in charge of the Survey until May 1, 1918, at which time I was appointed State Geologist.

Very respectfully,

WILBUR A. NELSON, *State Geologist.*

January 20, 1919.

To the Members of the Sixty-first General Assembly of Tennessee:

In accordance with the Act creating the State Geological Survey there is submitted for your investigation the administrative report of the State Geologist, covering the period from December 19, 1916, to December 19, 1918. We bespeak your careful consideration of the report, showing the important field occupied by the Survey and the work done by it during the biennial period that has just closed.

Respectfully submitted,

A. H. ROBERTS, *Governor, Chairman of the Commission.*

BROWN AYRES, *Secretary of the Commission.*

Administrative Report of the State Geologist, 1918

DEVELOPING OUR RESOURCES.

In the reconstruction period following the war, the State Geological Survey is as important a factor as it has been during the years of war which have just passed. Many problems have already been brought forward in which the Survey has taken an active part and supplied valuable data and information.

The possibility of oil and gas developments in the state is, at the present time, of great interest. It is one of our national resources with the greatest romance and lure. All the leading oil companies recognize the paramount necessity of having detailed geological work done on the structure of a region where there is a likelihood of oil being found, for it is known that certain types of structure are favorable for oil accumulations, and that if oil or gas is to be found such are the areas where the first drilling should be started.

This was the first work undertaken by the Survey on cessation of hostilities. The United States Geological Survey entered into a co-operative agreement to bear half the cost of this work and sent to Tennessee one of their experts to have charge of the field party which was to work the structure and oil and gas possibilities of a designated area, including portions of Clay, Fentress, Overton and Pickett counties. This area includes the old Spurrier oil eld which produced some oil in the nineties. When this work is completed it is hoped to map other likely areas in the state. Detailed studies and investigations of other mineral resources of the state are being continued by the Survey. A complete list of all reports, whether completed or in preparation, is given on pages 15 and 16.

Soil surveys are being made of the different counties of the state in co-operation with the United States Bureau of Soils, which also bears one-half the expense. In this manner a much larger area has been covered each year than otherwise would be possible if no co-operative agreement was in effect.

Educational work has been carried on throughout the state. In connection with this, an exhibit was prepared and shown at the State Fair, Nashville, Tenn.

A program for preliminary examinations of all water-power possibilities in Middle and East Tennessee has been started. The preliminary examinations already made have shown the presence of large amounts of undeveloped water power. After this investigation is completed a more detailed examination of all possible power sites and reservoirs is urgently needed, so that the state will be in possession of satisfactory information to furnish those interested in such developments. In the last month, an engineer, representing large Canadian interests, visited Tennessee for the purpose of investing in this section; but, although we had the water power, we did not have the detailed information necessary to show outside capital that it would be justified in making further surveys for that special project. With probably over one million undeveloped electrical horsepower in Tennessee, the necessity for this development work is apparent. Gauging stations have been established on many of the important streams and arrangements made whereby the United States Geological Survey pays half of this cost. The information obtained from such stations is essential to all parties that contemplate power developments.

New laws for the development and conservation of the natural resources of the state have been suggested and brought before the people of the state for their consideration. It is hoped that some of these suggestions will be enacted into law by the present legislature. Information has been furnished and reports prepared on cut-over land projects for the returned soldiers and sailors in accordance with the plans of the Reclamation Service of the United States Interior Department. Assistance was given in procuring a large acreage on the Cumberland Plateau on which the options secured were turned over to the government.

War Development.—During 1918, until the close of the war, the entire time and energies of the Survey have been devoted to war work. In war mineral work the Tennessee Survey has the record of being the first State Survey, out of more than a dozen, to publish a report on manganese localities and possibilities of development. This work and the report were made in co-operation with the United States Geological Survey. The value of this work to the people of the state is shown by the following extract from a letter which was

written to Washington: "The working (Reece or Taylor Valley Mine) is on the opposite side of the ridge from what was the mine at the time of your visit, at about same elevation, in an ore body twelve feet thick opened for a length of fifty feet and which as a whole runs thirty-three per cent ore averaging forty per cent manganese. . . . The ground was prospected by augers at your suggestion, and the discovery of the deposit is credited directly and in full to your geologic work and its overthrust fault theory by the Southern Manganese Corporation and others, who regard it a big help to the cause." The value of this work to the government is shown by the total tonnage of manganese that was produced by Tennessee during the war period, which amounted to 7,330 tons, while the total tonnage produced in Tennessee previous to the war was approximately 2,680 tons. The total tonnage produced in the United States in 1914 was only 2,635.

Tennessee was fortunate in containing certain minerals which were necessary for the successful carrying on of the war, such minerals having been imported previous to the war.

In addition to manganese, work was done on the ball clay deposits of West Tennessee, on the pyrite deposits of East Tennessee, and the utilization of pyrite from coal.

Mines are operating in West Tennessee on clays suitable for use in making steel crucible pots, glass pots, and high tension electrical insulators, as well as table and sanitary ware. Such materials should be used at home for the manufacture of clay products instead of shipping the raw materials to northern points, where they are now manufactured into the finished articles of commerce.

When the government, at the beginning of the war, called for an increased production of pyrite in this country, the operating mines responded and shipped a greater tonnage. The point was soon reached when all these mines were producing their limit. Then it was necessary to find new supplies. To open new mines, even if they can be found, takes time. The question was, how can the supply of pyrite be increased? So all the occurrences of pyrite were tabulated, and it was shown that the greatest possibility lay in utilizing the waste pyrite from the coal mines of our country. This was a by-product that most of the mines had considered a nuisance and thrown away. There was one mine in Tennessee that was saving its pyrite and shipping it to one of the chemical companies.

Representatives of the Survey visited most of the coal mines in the state, tested their pyrite, showed them how they could separate and save it economically, procured them customers at a good price, and had satisfactory freight rates made on this commodity. By these methods the output of pyrite was increased and more sulphuric acid was made at a time when it was badly needed by the government.

The Survey has continually furnished maps to the United States army officer in charge of the progressive military map of the United States and all mapping recently carried on by the Survey has been where it would be of the most benefit to the War Department. Assistance was especially given in furnishing base maps of certain sections of the government aviation flight area in West Tennessee.

Additional War Duties.—In addition to its regular duties, the Survey has assisted the State Council of Defense in exploration work throughout the state. War mineral agents were appointed in most of the sections of the state and a great impetus given to the development of war minerals.

The State Geologist was designated by the War Department as District Certifying Advisor for the Mining Industry of Tennessee. All applications for indefinite furlough for return to metal mining and metallurgical industries of enlisted men in the United States Army were taken up through the Survey.

With the cessation of hostilities, this work changed to obtaining from all the mining companies a statement of their labor shortage, if any, and assisting them in getting their former employes discharged from the army in order that they might be put to work immediately upon their return. Although this work added greatly to the Survey's duties, it was all taken care of with the voluntary assistance of a former secretary of the Survey.

Advertising Our Resources.—Information is furnished daily by correspondence and in person to those who call at the office, on the minerals and other resources of Tennessee. Localities are given that are susceptible of development. Of course, it is impossible to trace in every case the valuable part that this information plays in the total development that takes place in the industries of Tennessee, but often mines are opened and new industries are developed through the Survey's activities. One instance is mentioned to show the value of a State Geological Survey along these lines. A Georgia mining company wished a deposit of high-grade limestone to be used as a sub-

stitute for whiting, and for sale to the paint trade for other purposes. The Survey knew of such a deposit near East Sparta, Tennessee, which was brought to the company's attention, with the result that they acquired the property and opened a quarry during the summer of 1918.

The *Resources of Tennessee*, a quarterly magazine published by the Survey, is devoted to the description, development and conservation of our resources. It shows the outside world that we are "discovering America" in this section of the South and that Tennessee's remarkable minerals, her forests, and undeveloped water powers will eventually make it one of the leading mining and manufacturing states of the Union. It has not yet reached the rank to which it is entitled. The Survey's magazine, as well as its special bulletins, are sent to every state in the Union, as well as to the principal countries of Europe, Asia, Africa, and South America, and it is a common occurrence for requests to be received for additional copies.

GEOLOGICAL WORK OF THE SURVEY.

Barite.—An investigation of the barite deposits in the Sweetwater district, Tennessee, was made by Dr. C. H. Gordon in 1917, and published in the *Resources of Tennessee*, Volume VIII, No. 1, pp. 48-82.

Clay.—Work has been done by Mr. Rolf A. Schroeder on the ball clays suitable for war purposes, in Henry, Carroll, Madison and Henderson counties. Tests of these clays are being made by Prof. C. W. Parmelee of the Ceramic Department of the University of Illinois, under a co-operative agreement with the United States Geological Survey.

Coal.—The coal report, which has been in progress for some time by Dr. L. C. Glenn and the State Geologist, is being revised for publication.

Coal Pyrite.—This Survey co-operated with the United States Bureau of Mines in an investigation of coal pyrite, the work being done by E. A. Holbrook. This report is ready for publication.

General Geology.—In 1915, Mr. Bruce Wade was engaged in the detailed field work necessary to mapping the geological formations in McNairy County. According to the plans of the Survey, this was the beginning of the geological mapping of a belt of country lying mainly west of the Tennessee River and extending northward across

the state, known in geology as the Cretaceous area of Tennessee. The average width of this belt is perhaps forty miles. In the southern part of the state, it extends across the Tennessee River into Hardin County. In 1916, Mr. Wade, while a graduate student in geology at Johns Hopkins University, did an aggregate of two months' work, at such times as his studies permitted, on the McNairy County geological report. The latter part of the same year he completed the mapping of the Cretaceous deposits of Hardeman, McNairy, Hardin and Chester counties. Mr. Wade has been in active service in France for the past year or more but is expected to return soon and complete this work.

Dr. J. J. Galloway and Mr. H. N. Coryell were employed in studying the areal, stratigraphic, and economic geology of Rutherford County. This was done under co-operative arrangement between this Survey and the Agricultural Experiment Station, University of Tennessee. In connection with the geological mapping of this county, all of the field work was done for a soil map. Dr. Galloway has prepared the report on this county, which is now ready for publication. The base map of Rutherford County has been published.

Mr. Carl Dunbar completed his manuscript on the Devonian of West Tennessee in 1917 and it is now ready for the press.

The manuscript on the geology and mineral resources of the Crossville area by Mr. Charles Butts is ready for publication. This work was done in co-operation with the United States Geological Survey.

When the state geological map was published, a manuscript on the historic geology of Tennessee was also prepared to accompany the map. The work was done by Mr. Olaf P. Jenkins, and is now ready for the press.

Gravel.—In the work on mapping the Cretaceous formations in West Tennessee, Mr. Bruce Wade gave special attention to the gravel deposits that occur in the vicinity of the Tennessee River. His report on these gravels was published in the *Resources of Tennessee*, Volume VII, No. 2, pp. 55-98.

Limestone.—An investigation of the limestone along railroads in Middle Tennessee for fertilizer purposes was made by Mr. V. W. Blake and Thomas L. Bailey in the summer of 1917. This report is being prepared for publication and will include complete analyses of many of the limestones of this section. These analyses have already been completed by Dr. J. I. D. Hinds.

Manganese—As was true of many other minerals, the European war created a demand for manganese far above the average, and numerous inquiries came into the Survey as to its occurrence in Tennessee. A preliminary investigation of the manganese deposits of East Tennessee was made by the late Dr. A. H. Purdue in the fall of 1917, and an article on the manganese of Bradley County was published in the *Resources of Tennessee*, Volume VIII, No. 2, pp. 46-47.

In the summer and fall of 1918 extensive detailed work was done on manganese in East Tennessee in co-operation with the United States Geological Survey, Messrs. G. W. Stose and F. C. Schrader, representing the government, and Messrs. Arthur C. McFarlan and J. K. Roberts, representing the state. The work was inspected by Messrs. E. O. Ulrich and E. F. Burchard, of the United States Geological Survey. The material collected by these gentlemen was published in two papers in the *Resources of Tennessee*, Volume VIII, Nos. 3 and 4, pp. 153-198 and pp. 235-324, respectively.

The United States Bureau of Mines and the State Survey co-operated in work on the technology of manganese mining, the Bureau of Mines being represented by Messrs. Edmund Newton, W. R. Crane, and E. R. Eaton, one of whom spent most of the summer and fall of 1918 conferring with miners and encouraging the mine owners to increase their output. The report has been written by W. R. Crane and E. R. Eaton and is ready for publication.

Niter.—During the two months from July 15 to September 15, 1917, Mr. Thomas L. Bailey did field work on the caves of the Highland Rim and the Cumberland Mountains, for the purpose of ascertaining the quantity of niter deposits in these caves. The report, together with analyses on this work, was published in the *Resources of Tennessee*, Volume VIII, No. 2, pp. 85-142.

Oil and Gas.—During the last few years oil and gas have been eagerly sought in all parts of the country, and Tennessee has had its share of attention. The Glenmary oil field is still active, as shown in a report by Dr. L. C. Glenn, in 1918, published in the *Resources of Tennessee*, Volume VIII, No. 3, pp. 211-219. Dr. Purdue prepared an interesting report on the oil and gas conditions of the Highland Rim of Tennessee, which appeared in Volume VII, No. 4, pp. 220-228.

An article on the structure of the Waynesboro quadrangle with special reference to oil and gas, by Hugh D. Miser, was published

in 1917. The field work for this report was done under a co-operative agreement between the United States Geological Survey and the State Survey, the former bureau being represented by Mr. Miser. A detailed report on this quadrangle was published in the *Resources of Tennessee,* Volume VII, No. 4, pp. 199-219. Dr. A. H. Purdue gives some very interesting facts concerning the Glenmary oil field in the *Resources of Tennessee,* Volume VII, No. 2, pp. 103-108.

Field work on the oil and gas conditions of Overton, Fentress, Clay and Pickett counties is now in progress, under a co-operative agreement between the United States Geological Survey and the Tennessee Survey, Mr. Charles Butts representing the former survey and Messrs. Rolf A. Schroeder and H. E. Hamilton representing the latter. Mr. Butts has charge of the work, Messrs. Schroeder and Hamilton assisting. The result of this work will be published as soon as practicable.

Pyrite.—An investigation of the pyrite in the Ducktown region is in progress. This work is also co-operative and an economical report will be printed later.

Water Power.—Professor J. A. Switzer, hydraulic engineer of this Survey, has made a report on the undeveloped water powers of Tennessee in co-operation with the Knoxville Board of Commerce. This report is now in the press.

Several gauging stations have been and will be established in Middle and East Tennessee to determine the daily run off of the main streams. This work is being done in co-operation with the Water Resource Branch of the United States Geological Survey, who are represented by their district engineer, Mr. C. G. Paulsen.

Zinc.—In 1917, Dr. A. H. Purdue started an investigation of zinc in East Tennessee, but his field notes have not yet been worked up.

County Maps.—In 1917 and early part of 1918, C. R. Watkins, Jr., did field work in preparing the maps of Henderson, Bedford, Carroll, and Maury counties. In March, 1918, Mr. Watkins resigned and in May, Mr. H. E. Hamilton was appointed traverseman, and has been working on Carroll, Overton and Shelby counties. The following table shows the mileage traversed, by counties:

Henderson (complete), all railroads, county roads, and streams.
Bedford (complete), all railroads, county roads, and streams.
Carroll (complete), all railroads, county roads, and streams.
Maury (complete), all railroads, county roads, and streams.

Soil Maps.—In the summer and fall of 1918, John H. Agee, of the United States Bureau of Soils, finished the soil map of Maury County, the work being done in co-operation with the Tennessee Survey. The soil map, with a report, will be published by the above bureau.

A soil map of Meigs County was started by Mr. Agee in the fall of 1918, but was suspended on account of the weather, and this work was transferred to Bedford County. A soil map of Rutherford County has been prepared by N. H. Coryell.

WORK OF THE CHEMIST.

The following is the report of the chemist of the State Geological Survey of work done during the years of 1917 and 1918:

Dr. Paul C. Bowers was chemist of the Survey until the early part of December, 1917, when he resigned to take up war work. Dr. J. I. D. Hinds was appointed to succeed him.

Dr. Bowers' report, including time between November 25, 1916, and December 10, 1917, is as follows:

Determination of Mineral Specimens Sent to the Survey.—Reports made, 220; number of specimens reported, 450; number of mineral contents reported in specimens, 875.

Quantitative Analyses.—Partial chemical analyses, 26 samples; number of determinations, 70.

Dr. Hinds' report follows: Work during the year, including time between December 10, 1917, and December 31, 1918. Nearly all the analyses were partial. A few, especially those of the limestone, were almost complete. Two analyses of water, that from the sulphur well of A. C. Jones and that from Reelfoot Lake, were complete and exhaustive.

Qualitative Analyses.—Number of analyses reported, 209; number of specimens examined, 293; number of constituents determined, 568.

Quantitative Analyses.—Number of analyses, 207; number of determinations, 595.

Cave deposits, nitrates and potassium	69
Limestones	54
Pyrites	25
Manganese ores	19
Phosphate rocks	15
Petroleum	5

Coal	4
Iron ores	3
Waters	3
Miscellaneous	10
Total	207

WORK OF THE FORESTRY DIVISION.

In addition to the regular forestry work, the Forestry Division has devoted a portion of its time during this period to specific war work as requested by the Federal Forest Service.

Educational Work.—(1) Personal visits were made to landowners and persons in Weakley, Carroll, Hardeman, Chester, Williamson, Lincoln, Hamilton, Franklin, Knox, and Sevier counties to inspire reclamation work and for the purpose of studying forest fire conditions. (2) Forty-one articles have been written for publication. (3) Two forestry exhibits were given at the State Fair, Nashville, Tenn. (4) Motion pictures of forestry subjects were given in Nashville. (5) A good deal of time has been spent in effort to organize a much needed forestry association in Tennessee.

Practical Work.—(1) One new gully club was formed in Weakley County. (2) Twenty-four experiments were conducted personally by the Forester, seven of which are new. (3) Ten pounds of black locust seed were secured by the Forester; four farmers planted seed for their spring setting. (4) Thirty-five thousand black locust seedlings were set out by farmers in West Tennessee, 3,000 in Middle Tennessee. (5) Two experiments in dynamiting were conducted. (6) A co-operative plan for gully reclamation and farm forestry has been agreed upon by the Forestry Division of the Tennessee Geological Survey, the United States Department of Agriculture, and the University of Tennessee, Division of Extension. This plan should be of much assistance in extending the work of reclamation, and in helping the farmers to care for and promote the growth of their woodlands.

War Work.—(1) About a half million feet of black walnut was located for the purpose of getting walnut in the hands of the purchaser. (2) One week was spent in the woods of Tennessee estimating black walnut, looking to its use for the government. (3) Owners of black walnut were visited with the view of advising them about selling their black walnut for gunstocks and aeroplanes. (4) The Forester acted as listing officer for the 20th Engineers (Forest) Regiment for Tennessee. (5) Help was given in the publicity campaign

for wood fuel, in an effort to get farmers to deliver their wood to town for the relief of the coal situation. (6) The Forester visited Fayetteville and attended a meeting to assist in making effective plans for the working of a fuel company.

It is hoped in the coming year, through a forestry association, to further arouse the people of Tennessee to the absolute necessity of reclamation of Tennessee's waste and gullied lands and for the protection and conservation of her forests. The world is facing a period of reconstruction and the war has brought home the lesson as never before, that the conservation of a nation's natural resources means her prosperity.

GEOLOGICAL CORPS.

During the years 1917 and 1918, the following named persons were employed, most of them for only a part of the time, on this Survey:

Dr. A. H. Purdue was State Geologist until his death on December 12, 1917. Dr. L. C. Glenn was appointed Acting State Geologist and filled the place until May 1, 1918, when Wilbur A. Nelson, who had been elected *State Geologist,* took charge of the Survey.

Bruce Wade, *Assistant Geologist at Work on Cretaceous.*
R. S. Maddox, *Forester.*
J. A. Switzer, *Hydraulic Engineer.*
Paul C. Bowers, *Chemist.*
J. I. D. Hinds, *Chemist.*
C. R. Watkins, Jr., *Traverseman.*
H. E. Hamilton, *Traverseman.*
Rolf A. Schroeder, *Temporary Assistant on Clay Work.*
L. C. Glenn, *Temporary Geologist on Coal and Oil Work.*
C. H. Gordon, *Temporary Geologist on Marble and Barite Work.*
Arthur C. McFarlan, *Temporary Assistant on Manganese Work.*
Thos. E. Bailey, *Temporary Assistant on Cave Work.*
J. K. Roberts, *Temporary Assistant on Manganese Work.*
Carl Dunbar, *Temporary Geologist on Devonian of West Tennessee.*
J. T. Haden, *Temporary Draftsman.*
V. W. Blake, *Temporary Assistant on Limestone.*
Lewis M. Childress, *Secretary.*
Elizabeth C. Ingersoll, *Acting Secretary.*
Ruth C. Hall, *Secretary.*

Ruth Bulla, *Secretary.*

Roscoe Nunn, *Contributed Article on Climate of Tennessee.*

Park Marshall, *Contributed Article on Boundary Lines of Tennessee.*

S. T. Carman, *Temporary Laboratory Assistant.*

Hobart Watson, *Laboratory Helper.*

William Head, *Laboratory Helper.*

Mattie Clendenning, *Laboratory Helper.*

CO-OPERATIVE EMPLOYES.

The following named persons were employed a part of the time in 1917 and 1918, representing organizations that were co-operating with this Survey:

Hugh D. Miser, *representing the U. S. Geological Survey in the Waynesboro Quadrangle.*

Charles Butts, *representing the U. S. Geological Survey in oil and gas work.*

F. C. Schrader, G. W. Stose, E. O. Ulrich and E. F. Burchard, *representing the U. S. Geological Survey in manganese work in East Tennessee.*

Edmund Newton, W. R. Crane and E. R. Eaton, *representing the U. S. Bureau of Mines on manganese investigation.*

H. Ries, *representing the U. S. Geological Survey on Clay Investigations.*

E. A. Holbrook, *representing the U. S. Bureau of Mines on Coal Pyrite Investigations.*

C. W. Parmlee, *in charge of the Ceramic Department of the University of Illinois, and through an agreement with the U. S. Geological Survey tested clays in West Tennessee.*

John A. Agee, *representing the U. S. Bureau of Soils in soil surveys of Maury and Meigs counties.*

C. G. Paulsen, *representing the Water Resource Branch of the U. S. Geological Survey, placing gaging stations in Middle and East Tennessee.*

L. S. Hall, *representing the Water Resources Branch, U. S. Geological Survey, in stream gaging.*

W. D. Sterrett, *representing the U. S. Forestry Service, contributed an article on marketing woodlot products in Tennessee.*

W. R. Mattoon, *forstry specialist, representing the States Relation Service, U. S. Department of Agriculture, on farm forestry.*

PUBLICATIONS.

The following is a list of the publications of the Geological Survey from December, 1917, to December, 1918:

The Resources of Tennessee, Volume VII, Nos. 1, 2, 3, 4.

The Resources of Tennessee, Volume VIII, Nos. 1, 2, 3, 4.

Bulletin 19—Elevations in Tennessee.

Bulletin 20—The Larger Undeveloped Water Powers of Tennessee.

Map of Shelby County, published 1918.

Map of Decatur County, in press.

Map of Chester County, in press.

MANUSCRIPTS AND MAPS.

Some of the following manuscripts and maps are ready for publication and the others are in course of preparation:

The Historic Geology of Tennessee, by Olaf P. Jenkins. (Ready for press.)

The Marbles of Tennessee, by C. H. Gordon, T. N. Dale, and Oliver Bowles. (Ready for press.)

The Geology of Rutherford County (with map), by J. J. Galloway and H. N. Coryell. (Ready for press.)

The Tennessee Coal Fields, by L. C. Glenn and W. A. Nelson. (In preparation.)

Tennessee Phosphates, by J. S. Hook. (In preparation. Delayed on account of Mr. Hook going to war.)

Geology and Mineral Resources of the Crossville Quadrangle (with map), by Charles Butts. (Ready for press.)

Geology of McNairy County, by Bruce Wade. (In preparation.)

The Cretaceous Geology of Decatur County, by Bruce Wade (In preparation.)

The Cretaceous Geology of Hardin County, by Bruce Wade. (All of these papers probably would have been ready for press, but Mr. Wade went in training in 1917, and has been in France in active service for a year or more.)

Forests, Gullies and Reconstruction, by R. S. Maddox. (Ready for press.)

The Coal Pyrite Resources of Tennessee and Tests on Their Availability, by E. A. Holbrook and Wilbur A. Nelson. (Ready for press.)

The Mining and Preparation of Manganese Ores in Tennessee, by W. R. Crane. (Ready for press.)

Preparation of Manganese Ores, by W. R. Crane and E. R. Eaton. (Ready for press.)

Ball Clays of West Tennessee, by Rolf A. Schroeder. (Ready for press.)

Map of Henderson County. (In preparation.)

Map of Carroll County. (In preparation.)

Map of Maury County. (In preparation.)

Map of Bedford County. (Ready for press.)

The total amount expended for geological, soil and forestry work in Tennessee from December 19, 1916, to December 19, 1918, is shown in the following table. With the exception of the first item, this money was expended under co-operative arrangements between this Survey and other organizations:

TOTAL EXPENDITURES.

Expenditures as shown by the preceding Table of Expenditures	$32,885.42
Expended by the U. S. Bureu of Soils, May 1, 1917, to Oct. 1, 1918	2,729.41
Estimated expenses from Oct. 1, 1918, to May 1, 1919, $1,800 00.	
Expended by the U. S. Geological Survey (field expense)	772.03

APPROPRIATION REQUESTED.

The following appropriation is requested of the Sixty-first General Assembly and has been approved by the Geological Commission:

For the purpose of carrying on work of the Survey in accordance with Senate Bill No. 330, Chapter 569, Acts of 1909, from July 1, 1919, to July 1, 1921, salaries and expenses	33,000.00
To be applied toward publishing *Resources of Tennessee*	2,000.00
To be applied toward the publication of bulletins	6,000.00
For the maintenance of the Forestry Division of the Survey, salaries and expenses	10,000.00
Total	$51,000.00

APPROPRIATION FOR TWO MONTHS—MAY AND JUNE—BETWEEN OLD AND NEW APPROPRIATIONS.

For the purpose of carrying on the work of the Survey in accordance with Senate Bill No. 330, Chapter 569, Acts of 1909:

Salaries and expenses, also printing	$3,400.00
Forestry Division	800.00
Total	$4,200.00

TABLE OF EXPENDITURES FROM DECEMBER 19, 1916, TO DECEMBER 19, 1918.

	Office Salary	Field Salary	Field Expenses	Printing and Engraving	Equipment	Supplies	Postage	Freight, Drayage, Telep., Etc.	Miscellaneous	Total
ADMINISTRATION:										
General	$ 3,525.63	$1,199.95	$ 466.02	$ 51.40	$ 423.00	$ 214.77	$ 1.16	$ 187.50	$ 195.11	$ 6,264.54
REPORT AND SURVEY:										
General		501.42	156.72		314.61	86.75		1.30		1,060.80
LIBRARY					76.57					76.57
LABORATORY	3,366.11				2.75	115.03				3,483.89
AREAL GEOLOGY:										
McNairy County	175.00									175.00
Rutherford County	47.00									47.00
METALLIC ORES:										
Zinc in East Tennessee		243.86	74.81		8.40	17.34				344.41
FUELS:										
Coal		211.66								211.66
Oil and Gas, Special		96.66	11.89							108.55
BUILDING STONE:										
Marble	85.00	12.00	29.42							126.42
STRUCTURAL ROCK PRODUCTS:										
West Tennessee Clay (war work)	129.74	412.54	372.85		64.34	147.74	4.78	1.20	15.75	1,148.94
CHEMICAL AND ARTS MATERIALS:										
Limestone for Fertilizer		139.94	69.45				.49	1.91		211.79
Niter	1.62	99.20	82.36		1.40		.60			185.18
WATER RESOURCES:										
Undeveloped Water Powers	74.75	35.00	66.20	5.52						181.47
Gauging Stations			178.17							178.17
SOIL SURVEY:										
Shelby County	20 00		4.50							24.50
Maury County		200 00	213.97		2.35		.25	2.21		418.78
Rutherford County	20.00									20.00
FORESTRY:										
General	2.515.15	2,486.85	696.97	749.82	91.34	46.34	8.58	50.89	16.15	6,662.09

INFORMATION:										
General	2,823.44	276.66	120.25	.50	92.03	130.55	286.08	1.60		3,731.11
Photos					17.85					17.85
STATE EXHIBIT		25.00	44.00		1.30			19.13		89.43
RESOURCES OF TENNESSEE	863.82	120.00	308.15	1.667.52		31.81	58.92	5.04	.40	3,055.66
COUNTY MAP:										
McNairy County				384.16						384.16
Rutherford County			.50							.50
Henderson County		260 00	255.31		.80		.35	1.44		517.90
Bedford County	5.00	311.00	342.19					.50		658.69
Carroll County		1,084.33	825.28	2.85	54.71	15.20	2.11	8.13	4.10	1,996.71
Shelby County			3.10	60 00					18.38	81.48
ELEVATIONS IN TENNESSEE	45.00			413.91						458.91
WAR WORK:										
Manganese	41.76	386.66	424.81	22.50	74.65	8.90	4 00	71.91	3.25	1,038.44
Coal Pyrite	50.00	215.50	160.16					3.59		429.25
Total	$ 13,789.02	$8,318.23	$4,907.08	$3,358.18	$1,226.10	$ 814.43	$ 367.32	$ 356.35	$ 253.14	$ 33,389.85

Due to war conditions there were delays in paying several large bills for work on manuscripts and for printing that has been contracted for but not completed. These accounts will bring the total expenditures up to the amount appropriated.

ACT ESTABLISHING THE GEOLOGICAL SURVEY.

The bill establishing the State Geological Survey was passed by the Fifty-Sixth General Assembly of Tennessee in 1909, and is as follows:

CHAPTER 569.

SENATE BILL No. 330.

(By Messrs. Greer, Huffaker, and Neal.)

A BILL to be entitled An Act to establish and create the bureau to be known as the State Geological Survey; defining its objects, powers, and duties; providing for the appointment of a State Geologist, and defining his powers and duties; permitting co-operation with Federal and State bureaus in furthering the objects of this Act; providing for the publication of the results of the Survey; providing for the collection of exhibits of the natural resources of the State, and for the final disposition of the equipment and property of the Survey; authorizing entrance upon private lands in the prosecution of the work of the Survey; and making the appropriations for the enforcement of this Act.

SECTION 1. *Be it enacted by the General Assembly of the State of Tennessee*, That there be, and is hereby, created and established a bureau to be known as the "State Geological Survey," which shall be under the direction of a Commission to be known as the "State Geological Commission," composed of the Governor (who shall be ex-officio Chairman of said Commission), the State Commissioner of Agriculture, the State Mine Inspector, the President of the University of Tennessee, the Chancellor of Vanderbilt University, and the Vice Chancellor of the University of the South.

SEC. 2. *Be it further enacted*, That the said Commission shall have general charge of the State Geological Survey and shall appoint as Director a Geologist of established reputation, who shall be known as the "State Geologist," and upon his recommendation such associate geologists, assistants, and employes as may be necessary to carry out successfully and speedily the work of the Survey.

The Director, associates, assistants, and employes appointed under the provisions of this Act shall receive such compensation as shall be determined by the Commission. The said Commissioners shall serve without compensation, but shall be reimbursed for actual expenses incurred in the performance of their official duties.

SEC. 3. *Be it further enacted*, That the said Commissioners shall meet for organization within thirty days after the passage of this Act, and shall appoint a Director as soon thereafter as possible. The regular meetings of the Commission shall be held on the first Wednesday in May and the first Wednesday in November of each year in such place as the Commission shall determine.

SEC. 4. *Be it further enacted*, That it shall be the duty of the State Geologist, subject to the approval of the Commission, to organize and direct the work of the State Geological Survey in field and office; to determine the character, order, and time of publication of the reports of the Survey, and to direct the preparation, printing, and distribution of the same; to arrange for co-operative work with the various Federal and State scientific bureaus where such work shall redound to the interest of the people of the State; to appoint such associates, assistants, and employes as may be necessary to carry out successfully and speedily the work of the Survey; to procure and have charge of the necessary field and office supplies and other equipment, and supervise the acquisition, care and distribution of the collections of the State Geological Survey; and to perform such other work as may be necessary to the successful conduct of the Survey. He shall prepare a report to the General Assem-

bly before each meeting of the same, setting forth the progress and conditions of the Survey, together with such other information as the commission may deem necessary and useful.

SEC. 5. *Be it further enacted,* That the said State Geological Survey shall have for its objects and duties the following:

1. A study of the geological formations of the State, with especial reference to their economic products, including coal, oil, gas, ores, fertilizers, building stones, road-making materials, clays, cement materials, sands, soils, forests, mineral and artesian waters, drainage of swamps, streams, and water powers, and other natural resources.

2. A study of the character, origin, and relations of the soils of the State, with especial reference to their adaptability to particular crops, the maintenance of soil fertility, and the conservation and utilization of supplies of natural fertilizers.

3. A study of the road-making materials of the State, with reference to their character, distribution, and the best methods of utilizing the same.

4. A study of the occurrence and availability of underground water supplies.

5. An investigation of the forests, streams, and water powers of the State, with especial reference to their conservation and development for industrial enterprises.

6. A study of the swamps and other non-tillable lands of the State, with reference to their reclamation for agricultural purposes.

7. A study of the physical features of the State, with reference to their bearing upon the occupations, physical welfare, and intellectual pursuits of the people.

8. The preparation of special reports with necessary illustrations and maps, which shall embrace both general and detailed descriptions of the geology, topography, and natural resources of the State.

9. The preparation of special geologic, topographic, and economic maps to illustrate the structure, relief, and natural resources of the State.

10. The consideration of such other scientific and economic questions as in the judgment of the Commission shall be deemed of value to the people of the State.

SEC. 6. *Be it further enacted,* That the regular and special reports of the State Geological Survey, with proper illustrations and maps, shall be printed and distributed and sold as the Commission shall deem best for the interest of the people of the State and as said Commission may direct, and all moneys obtained by the sale of said reports shall be paid into the State treasury. The said Commission shall cause to be prepared a report to the General Assembly before each meeting of the same, showing the progress and condition of the Survey, together with such other information as they may deem necessary and useful, or as the General Assembly may require; *provided, however,* that the Commission shall have the right to print and distribute said reports.

SEC. 7. *Be it further enacted,* That after having served the purposes of the Survey, all material collected shall be distributed by the Director to the educational institutions of the State in such manner as the Commission may determine to be of advantage to the educational interests of the State; *provided, however,* that if deemed advisable, the Commission may first use such portion as may be necessary to establish a permanent exhibit of the natural resources of the State. On the completion or discontinuance of the State Geological Survey, the Commission shall cause all records, notes, books, reports, charts, maps, manuscripts, instruments, and other equipment and property of the Survey to be placed in charge of a suitable custodian, to be held subject to final disposition by the General Assembly; *provided, however,* that any field or other equipment which the Commission shall deem it undesirable to preserve may be sold as the Commission may direct and the money turned into the State treasury; and, *provided further,* that the copies of the reports

of the Survey left on hand for distribution shall be distributed by the custodian in such manner as shall be for the best interest of the people of the State.

SEC. 8. *Be it further enacted*, That the said Commission is hereby authorized to enter into co-operation with the United States Geological Survey and other scientific bureaus of the Federal and State governments for the prosecution at joint expense of such work in the State as shall be deemed of mutual interest and advantage, and under such conditions as said Commission may deem to be for the best interest of the people of the State.

SEC. 9. *Be it further enacted*, That in order to carry out the provisions of this Act, it shall be lawful for any person or persons employed hereunder to enter and cross all lands within the State; *provided*, that in so doing no damage is done to private property.

SEC. 10. *Be it further enacted*, That for the purpose of carrying out the provisions of this Act, fifteen thousand dollars ($15,000) annually for the years 1910 and 1911, or so much thereof as may be necessary, is hereby appropriated out of any money in the State treasury not otherwise appropriated, and the State Treasurer is hereby authorized to pay out the same on the warrants of the Comptroller upon the presentation of the proper vouchers by the Chairman of said State Geological Commission; *provided*, that the appropriation made herein shall not be available until May 1, 1910.

SEC. 11. *Be it further enacted*, That this Act take effect from and after its passage, the public welfare requiring it.

Passed April 30, 1909.

WM. KINNEY,
Speaker of the Senate.

M. HILLSMAN TAYLOR,
Speaker of the House of Representatives.

Approved May 1, 1909.

MALCOLM R. PATTERSON,
Governor.

Forests, Gullies and Reconstruction

By R. S. Maddox.

INTRODUCTION.

The world war is over. We have been shaken by it out of our lethargy and, though a rude awakening, it has revealed to us truths which perhaps we might by no other means have so certainly apprehended. Each country which was engaged in the conflict is now endeavoring to find herself and is taking stock, as it were, so that she may start again upon a firm basis for future prosperity. In this stock-taking certain facts become apparent. Professor J. W. Toumey, director of the Yale School of Forestry, says: "Victory is with the army whose country has the greatest iron mines and smelters, the largest areas of waving grain, and an abundance of wood. . . . If the French had had no forests at the outbreak of the war, France would be devastated today and the nations of Middle Europe feasting in the halls of Paris." It was found during the war that there was no successful substitute for wood—that the soldiers had to be housed in wooden cities instead of tents; that railroad ties, trench supports, roads for transporting artillery, all had to be provided from wood. In addition, our country was scoured for black walnut and black locust to be used for gun stocks, aeroplane stocks, and tree nails for shipbuilding, besides hundreds of millions of board feet of spruce cut from our northeastern and northwestern forests. The fact that our northwestern country alone supplied in one month for aeroplanes three hundred million board feet, may serve to give a small idea of the vast amounts utilized. The paramount importance of food production has been also forcefully brought home to us. Fortunately, our country was not devastated by the war, but the great supply of timber needed from our forests, the enormous quantities of foodstuffs necessary at home and for our allies abroad, should keep us mindful of the incalculable value of our forested and agricultural lands, and make us ever vigilant and active in their conservation.

FORESTED AND FARM LANDS.

Heretofore Tennessee has been noted for the abundance of her hardwood timber and fine agricultural lands. We might say that Tennessee

yet has a good acreage of woodlands and an abundance of agricultural lands, but we must at the same time recognize the fact that she has been wasting these resources. Let us consider the forest problem first.

FORESTS.

Forests are the lands which we have in tree growth. Ours in Tennessee have been reduced by constant clearing to thirty or thirty-five per cent of the state's area. Much of this area has already

FIGURE 1. A portion of Tennessee's mountain land where fires have burned without interference. There is no evidence that any timber was ever cut from this area. The young growth has sprung up since the fire three years previously. There should be a heavy stand of good trees.

been cut over, during which process the best trees have been removed. These portions are situated chiefly on the Highland Rim, Cumberland Plateau and the mountains of East Tennessee. These, together with the more scattered woodlands over the state, constitute Tennessee's forests. They contain in sum total an abundance of trees, but not an abundance of timber.

Causes of Forest Conditions.—There are several causes which have contributed to the condition of our forests. The acreage of these wood-

lands has been reduced too rapidly in proportion to our population, making the forest area comparatively small. In addition, the best trees have been removed from the forests, without any plan for securing new growth and protecting it. Forest fires have been permitted to run unchecked through not only the cut-over areas, but also through those sections yet untouched by the axe. Promiscuous grazing, which has in many cases been closely related to the burning of forest fires, has also helped to diminish the new growth. This comes from permitting stock to graze on burned-over areas, consuming and trampling the remaining young trees.

Importance of Forests.—In the introductory paragraph of this article, it has been shown how important a country's timber supply is to her in an emergency. Vital as forests are for timber production in peace, as well as in war times, they are equally necessary for other uses. Forests are of inestimable value for the protection of our stream flow; without them the rains falling upon our watersheds would have little or no obstruction, thus causing floods down the bare mountain sides, followed by severe drought. In this way, obviously, forests are necessary to agriculture and other industries. The development of water power throughout the state is absolutely dependent upon the forests. Woodlands, too, are the habitat for wild life of all kinds, a part of any state's recognized resources. Fires should be kept out, reforestation should be done, harmful grazing stopped and careful cutting practiced, thus enabling Tennessee to have full stands of valuable forest trees.

GULLIES.

Description.—In considering gullies, we might say lands may be classed as waste when they are badly gullied or sheet washed, so as to be practically useless and a positive source of harm. Without an actual survey and a definite standard of classification, it is impossible to state the acreage of waste lands in Tennessee. From estimates, however, through observation while working in different sections of the state and traveling through others, the writer does not hesitate to say that such lands will most conservatively reach seven hundred and fifty thousand acres. Any man from the car window or public road can easily observe these conditions. Fields of moderate slope and deep soil once cultivated are so badly cut up with gullies that they can no longer be tilled; then being useless they are turned out to waste. Slopes with

FIGURE 2. The type of hill and mountain land that should never be cleared. Such areas should be kept growing timber. The corn rows are noticeable in the picture

FIGURE 3. Mountain land cleared and used for pasture, which should always grow forests. The sloughing off of the surface is very noticeable.

shallow soil have washed until the underlying rocks are so close to the surface that cultivation is practically out of the question. Steep hills and mountain sides cleared and worked for a comparatively short time have been, through erosion, virtually ruined for years to come; lands of this same type also when used for pasture after clearing have sloughed off and eroded to such an extent that they are useless.

Causes of Gullies.—Chief among the causes for these waste and gullied lands are: First, *the character of the soil, i. e.,* the soil constituency. Some soils do not erode rapidly because of the heavier, stiffer clays composing them. Others erode more rapidly because of the admixture of sand with the clay; this is particularly so in West Tennessee. Primarily because of this soil constituency, this section of the state, although comparatively level, is subject to heavy erosion if neglected or abused. Second, *shallow plowing.* This is responsible for a great share of the waste lands all over the state. A thin layer of plowed ground is soon saturated with water; added precipitation then cannot soak rapidly enough into the hard subsoil and therefore runs off over the surface, causing sheet wash or gullies. Third, *constant crop production* (which is not the same as cultivation) *without renewal of fertility.* This lies at the root of much washed land in Tennessee, for land must be renewed in fertility by decayed vegetation in order to render it capable of receiving and retaining necessary moisture. Decayed vegetation itself is a great water container and makes land porous. This can be observed in the mushy decayed remains of an old straw pile. When the vegetable matter, or humus, is quite exhausted the soil becomes less porous and the water runs off more readily over the surface. It is interesting to note that humus changes the color of soil. To cite an example, some clays in the state are very red when lacking in vegetable matter, but with the addition of humus they become a rich chocolate shade. Fourth, *rows running up and down the hill.* This is a very common and harmful practice connected with farming; it causes the surface soil to be carried off down the furrows, exhausting the fertility and causing gullies. Fifth, *clearing of hillsides too steep for cultivation.* Such areas cannot be maintained under the present system of agriculture; even as pasture lands they slough off through the trampling of stock, finally developing into gullies.

Injuries from Gullies.—From an economic standpoint one observes several facts concerning waste lands. Their presence depresses prop-

FIGURE 4. A badly gullied area on the farm of Will Roberson, Dresden, Weakley County, Tennessee, as it appeared before reclamation was started. Work was begun on it August, 1917, by building brush dams and plowing off the gully banks.

FIGURE 5. The same area as Figure 4, showing the black locust and bushes in July, 1918, which were set out in March, 1917. The letters A and B in Figure 4 and 5 show the same places before and after reclamation was begun.

erty values as a caved-in roof affects the value of a house. Also they consume, instead of produce; they eat in upon new land, convey fertility away from the farm and turn good fields into waste by depositing sand, stone and gravel over them. Sometimes they convert bottom lands into swamps, by choking streams with sand, thus causing water to spread over the bottoms. Because of increasing waste lands, new areas of woodlands must be cleared to supply the needed acreage for cultivation and thus forests are sacrificed.

Prevention and Cures.—If there were no harm resulting from waste lands, there would be no practical reason for preventing or reclaiming them, but they are a menace, and the need for restoring them is urgent. There are preventions and cures for these sick areas. Among the preventive measures that might be used are the following: Slopes too steep for cultivation and lands too shallow in soil for tillage should be left uncleared; fertility in cultivated lands should be maintained by supplying regularly the necessary vegetable humus; cover crops should be grown, especially on hillside fields, which should not be allowed to lie bare during the winter; rows should never be run up and down the hills and the ground should be plowed deep. Now for the cures: Practically all, to say the least, of Tennessee's waste lands can be reclaimed, if not for raising agricultural crops, then for raising timber. In stopping erosion, the main object is to catch and hold the escaping dirt. This can be done by making the same agency that washed away the land help build it up again. Thus as the water flows down the channels, carrying the dirt, it must be checked by some obstruction in the bottom of the gullies and forced to deposit its load. These obstructions are merely dams and can ordinarily be built easily and cheaply out of brush. Catching the dirt is but the first step in the reclamation project. It is necessary, next, to secure a permanent growth on the dirt which has been caught by the dams. Usually this can be obtained only by planting, since dams rot out in a few years and voluntary growth by that time rarely is sufficiently strong to hold after the dams are gone. It is often desirable and advisable to plow off the banks, so the dams may more rapidly catch dirt on which to set out growths. Black locust bushes, Bermuda grass and honeysuckle vines have so far proved most successful for this purpose; they have a permanent, strong root system. In addition, they yield a revenue in the form of posts and grazing. Black locust should be cultivated the first year. During this tillage, soy beans and stock peas fre-

FIGURE 6. A very badly eroded area of waste land on the farm of L. C. Brown in the northeastern part of Weakley County, Tenn., near Boydsville, Kentucky. The dams were built in the summer and fall of 1917, the banks plowed off as shown in the picture and the entire area set in black locust in the spring of 1918.

FIGURE 7. The same area as Figure 6, showing the black locust bushes in July, 1918, which were set out in March, 1918. By the time the dams decay the locust trees will have the ground thoroughly bound with their roots.

quently can be planted with them as fall pasture for hogs. No other stock, however, should be permitted in a locust grove, since they injure or kill the young trees by browsing upon them and tramp the ground hard upon the roots. In the spring of 1916 fifty thousand black locust seedlings, in the spring of 1917 sixteen thousand black locust seedlings, and in the spring of 1918 thirty-five thousand black locust seedlings

FIGURE 8. Three-year-old black locust on a once badly gullied area on the farm of Leslie J. Buford, Franklin, Tennessee. The gullies were plowed after dams were built, some dynamiting done, and the area (about two and a half acres) set in black locust in the spring of 1915. Picture taken November, 1918.

were planted in West Tennessee alone. The Forestry Division has a good many areas successfully undergoing reclamation.

The state must keep vigorously working on her forest and waste land problems. Gullies are a menace both to forests and to agricultural lands; forest fires are a menace to woodlands and agricultural lands. He would be a poor fisherman who would go out constantly with his nets full of holes. Waste land on the farm and fires in the woodlands are holes in the net. The holes must be mended.

The Mining and Preparation of Manganese Ores in Tennessee

By W. R. Crane.*

INTRODUCTION.

The character of minerals and their occurrence often have important bearings upon the work of mining and preparing for market; it is therefore considered not only desirable, but necessary in this connection, to discuss briefly the different forms of deposits. Further, the knowledge of the mode of occurrence may be of considerable service in the location of ore deposits and in proving their extent and value.

The minerals found in the manganese districts of East Tennessee are pyrolusite, psilomelane and manganite, the first two occurring in the greatest abundance, although the last mineral is often found in considerable quantities. The manganese oxide mined at the Henley mine in the Greenback district is probably one of the important occurrences of manganite in the state. The carbonate of manganese, rhodochrosite, is found in what promises to be a fair-sized deposit in the East Fork Mine near Sevierville. The other oxides of manganese occur in deposits of varying size and importance in the Johnson, Sweetwater and Cleveland districts, being largely pyrolusite and psilomelane.

TYPES OF DEPOSITS.

General Classes.—There are a number of types of manganese deposits, but most of the occurrences can be grouped under two general types, namely, replacement and cavity filling. In Tennessee, as in most of the manganese districts of the Southern States, there is indisputable evidence that the manganese has been collected from widely scattered sources and has been concentrated from solution in underground waters. A discussion of the source and origin of the ores is not in the province of this paper, but to secure an adequate idea of the

*The field work on this report was done under a co-operative agreement between the State Geological Survey and the U. S. Bureau of Mines. This report is published by permission of the director of the U. S. Bureau of Mines.

character and form of the ore deposits now worked, it is desirable to consider briefly their mode of formation.

The manganese deposits of East Tennessee are associated with iron ores, particularly limonite and hematite, and occur in limestones, dolomite and sandstone. It is also possible that certain deposits may occur in shale beds.

The formations in which the manganese occurs are, in order from below upward, Knox dolomite, Chickamauga limestone (Lenoir of Ulrich), Holston marble, Athens shale, and Tellico sandstone. Probably the larger number of known occurrences of workable deposits are in dolomite, marble and sandstone, but owing to the wide variations in thickness and extent of these formations, also owing to their excessive decay, it is not always possible to determine exactly to which formation a given deposit may be referred.

Replacement Deposits.—By replacement the manganese minerals have taken the place of the various formations and as the immediate source of the manganese was the solutions of the minerals in the underground waters, such replacement naturally took place in fractured areas, in fissures and in bedding and joint planes. Wide variations in thickness and extent of ore bodies would result from such conditions of formation and such are observed in the deposits of this region. The decay of the formations in which replacement took place or where the minerals were deposited, has in the majority of cases freed the minerals, leaving them in the clays, sands and other residual materials. Ample evidence exists, however, to demonstrate that the minerals formerly occurred in the limestones, sandstones and dolomites, as they are still found in these formations, where the decay has not proceeded sufficiently far nor sufficiently deep locally to have separated the mineral from the parent rock.

Manganese occurs in and is a part of the Holston marble or is closely attached to it in the mines in the Sweetwater and Cleveland districts, particularly the McGuire and the Flint Springs mines.

Manganese is also found in the Knox dolomite at the East Fork Mine in the Sevierville district. In the majority of cases the oxides occur in clays and sands, while in the East Fork Mine the carbonate is found in depth in the dolomite, the decay of which has not yet freed the manganese. However, in the upper portions of this deposit the decay of the dolomites has exposed the carbonate to oxygen-bearing waters, which have altered the carbonate to oxides, particularly the

mineral psilomelane; in this deposit there are found, therefore, both the unaltered carbonate and the altered product or oxide.

Residual Deposits.—The ores of manganese are in the case of the oxides largely mixtures of mineral and clays or residual products; however, in the case of the carbonate the mineral is still inclosed in the parent rock and is a true ore. The fracture-filling or breccia type of ore is a class intermediate between those above mentioned. The usual occurrence of manganese minerals in clays and sands might more appropriately be spoken of as wash-dirt than ore, as by the simple

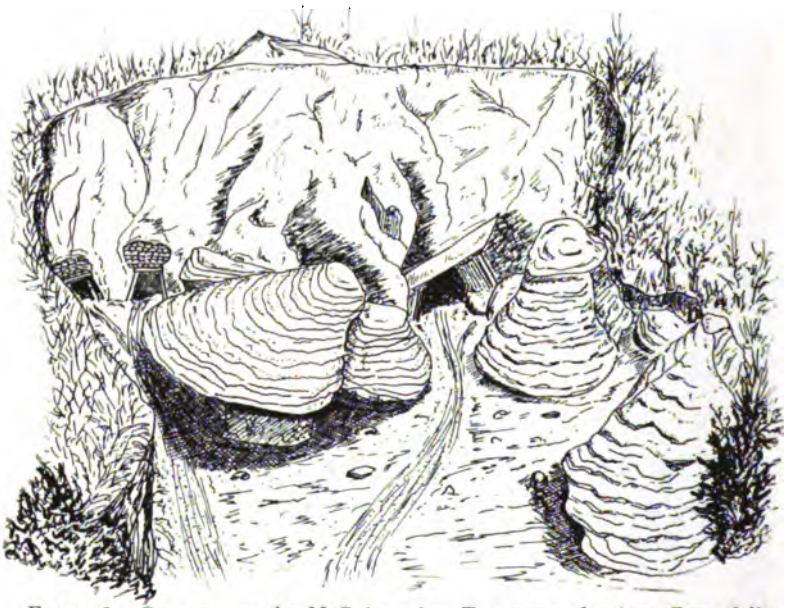


FIGURE 1. Open cut at the McGuire mine, Tennessee, showing effect of limestone pinnacles on method of mining.

process of washing the mineral can be separated from the wastes, while with the rhodochrosite ore preliminary concentration or roasting may be desirable or necessary.

Probably owing to the absence of limestones particularly susceptible to the solvent action of ground waters, the decay of such rocks has not been as excessive as in other localities where the depth of the residual deposits is often one hundred feet or more. That the decay of the limestones and dolomites has been great and is undoubtedly still continuing is evident on examination of the surface and under-

ground workings of the various manganese mines. The decay is also extremely irregular, as is shown by the surface of the bed rock and the presence of large boulders of limestone resting upon it.

It is evident, then, that there are three general kinds of ore mined in this region, namely, the mineral-bearing clays, the breccia ore, and the hard ores of manganese and dolomite, each of which requires a wholly different method of mining and treatment in its preparation as a marketable product.

The two general types of deposits have been brienfly dsicussed particularly with respect to the effect that their occurrence has upon mining and preparation. Aside from the types of deposits there are a number of forms that also have important bearing upon methods of mining and preparation. With the forms as with the types of deposits, a considerable number can be grouped together under a few typical classes, the most important of which are the blanket and irregular forms.

Blanket Deposits.—The blanket form of deposit is probably the most important, both with regard to the quantity and value, the irregular form being a close second. The blanket form is a replacement type of deposit and is found adjacent to and often firmly attached to the Holston marble. Occasionally decay of the marble has proceeded below and beyond the blanket of manganese, consequently freeing it from the marble, upon or close to which it is still found, unless broken up and removed by earth movement and erosion. The blanket of ore conforms in a marked degree with the lay of the bed rock, lying on the flat-lying portions and riding over the irregular masses and boulders, forming a veritable blanket of manganese. In many respects the blanket resembles a bedded deposit, except for its extreme irregularity and lack of conformity with the other and associated formations.

The manganese minerals composing the blanket have a wide range in character and value, and taken as a whole are of greater value than those found in other forms of deposits. In certain localities the grade of the oxides is as high as 55 to 56 per cent metallic manganese. Considerable quantities of iron ore are associated with the blanket form of deposit, occurring in the marble bed rock, in blanket form above, below and interstratified with the manganese. The blanket form of deposit, when broken up and mixed with clays and sands, is considered under the class of mineral-bearing clays or wash-dirt, but owing to its occurrence, such material is difficult to handle and treat sys-

tematically in any regular washing or concentration process, being in large and irregular masses.

Irregular Deposits.—The irregular form of deposits is much more varied in its character and mode of occurrence than is the blanket form, and may be subdivided into a number of classes, such as nodular, granular, soft and breccia.

The nodular and granular forms of mineral constitute the most irregular deposits and are therefore the most difficult to locate and determine with respect to their value and extent. The nodular form differs from the granular in that the latter is fragmental, while the former is composed of complete pieces as formed by replacement in the formation from which it came. The occurrence of the two forms is identical within the deposits and has no order at all except as controlled by the extent and dip and strike of the formations in which they are contained. Occasionally the deposits assume a banded form, continuing for some distance with a considerable degree of persistency, then terminating in stringers or enlarged masses. Owing to the thickness of the enclosing formations, it is practically impossible to employ the available information concerning them as a guide in the economic development of the irregular deposits of manganese.

The soft or wad forms of ore are similar in character to the nodular and granular forms, but are, as a rule, more variable as to value, usually being very low in grade. It is probable, also, that the amount of such manganiferous clays is greater than of the other forms mentioned; however, they are of much less consequence economically than the nodular and granular forms.

The last form of irregular deposit considered is the breccia ore, which while very irregular, may prove to be of greater economic importance than the other forms, due to the greater tonnage that such deposits probably contain. The breccia ore in itself is hard, being composed of quartzite, sandstone or chert, which has been extensively fractured by earth movement, and later cemented together again by manganese minerals. Intimately associated with such deposits are other irregular deposits of nodular and granular manganese, which in certain instances may have been derived wholly or in part from the breccia deposits. The combination of clay and manganese with hard ore presents added difficulty to mining and treatment, but is not insurmountable. The grade of the breccia ore is low, probably seldom exceeding 15 per cent and possibly averaging somewhat below that

figure; however, owing to the relatively large amounts of such ores, its mining and treatment are worthy of careful consideration. Probably the most extensive deposit of breccia ores so far developed in eastern Tennessee is on the White Oaks property in the Cleveland district, although there are other occurrences, particularly in the Johnson district.

FIGURE 2. Face of open cut showing occurrence of manganese, which is common form assumed by nodular and granular deposits. White Oaks property, Tennessee. *a*, Ferrugenous clay; *b*, manganese; *c*, red and brown clays, banded. This shows occurrence of common form of wash-dirt.

Transported Deposits.—There still remains another form of irregular deposit, which is secondary in its origin, as are certain parts of all deposits of manganese regardless of their origin and form. It is evident from what has been said regarding the blanket form of deposit that there is a certain amount of regularity in its occurrence, both with respect to its position in the bed rock and to its continuity. When, however, a blanket deposit is broken up by decay of the bed rock and the erosion of the residual deposit, the more resistant masses of manganese are transported considerable distances from their point of origin and are often buried in beds of clay. Deposits of high grade manganese are thus formed, but occur in most irregular forms, being scattered indiscriminately throughout extensive beds of clay.

Conclusion.—It is evident from the above discussion of the occurrence of manganese in the various forms of deposits that considerable

care must be taken in the various mining operations, such as prospecting, development and mining. The geological sequence of formations once understood is, however, of great assistance in the location of ore deposits, and may in many cases be the determining factor in regard to the possible extent of workable deposits. Deposits that have been located and give promise of having a fair amount of ore, must be developed and mined in such a way as to safeguard the operations against conditions arising from irregularity and uncertainty of occurrence. The character of the ore deposits determines the methods employed in mining, and in a similar manner the character of the ores mined, determine the methods of preparing them for market; the variableness in quality and the uncertainty in quantity being noticeable through the entire work of the mining and preparation of the ores.

METHOD OF MINING.

The methods employed in mining the manganese ores and mineral-bearing clays are somewhat varied, but owing to the limited extent of the deposits and their extreme irregularity, also due to their occurrence in superficial deposits, there are few or no operations that approach a size productive of any considerable tonnage. Most of the operating properties are producing less than fifty tons of finished or clean mineral per month. Aside from the difficulties arising from the uncertainty and irregularity of the deposits, there are other obstacles often encountered, such as scarcity of water and fuel, and long hauls to the railroad. The high price of manganese has, however, stimulated production through the development and operation of numerous deposits that could not otherwise have been worked at a profit.

The various operations necessary to the mining of manganese may be outlined as follows: Prospecting or testing, development, and mining or extraction of the ore or wash-dirt. Ordinarily in mining work these operations are more or less distinct and separate, but with shallow workings and those limited in size there may be and usually is a merging of the work of prospecting, development and mining, which is particularly noticeable in manganese deposits.

Prospecting or Testing.—The prospecting for manganese deposits by test-pits or trenches should not be attempted until a thorough examination of the surface of the property has been made. Surface indications of mineral are desirable although not absolutely essential, as

the occurrence of the ore may be such as not necessarily to expose the deposit, or wash from the deposit, on the surface. A careful examination of outcrops often indicates the probable position of a deposit, but such geological relations are only indicative; deposits being the exception rather than the rule, do not always occur where they might and logically should.

When particles and masses of manganese are found on the surface it is evident that they must have resulted from the breaking up of a deposit further up the slope, although it is possible the deposit from which they came may have been completely removed. It is but logical that search should be made directly up the slope upon which the surface indications are found.

The prospecting or testing of manganese properties is probably one of the most important parts of mining, for by prospecting the character and value of a deposit is determined, and upon the information obtained decision is made regarding the advisability of purchase and development. That too great care cannot be taken is shown by the relatively large number of properties that have been purchased, developed to a limited extent, and abandoned through failure to find mineral in workable amounts. The purchase of property and its subsequent proving by testing shows anything but good business sense, but has been done repeatedly and will probably continue to be done regardless of repeated failures.

Prospecting by sinking test-pits is undoubtedly the most satisfactory method owing to the irregularity of the deposits; however, bore holes 5 to 8 inches in diameter have been employed, being drilled by churn drill. The objection to drilling, or in fact testing by small-size holes, is the danger of underestimating or of magnifying the results obtained, for a good body of ore might be passed by with a margin of only a few inches, but no evidence of it obtained; while on the other hand a small mass or stringer of ore drilled through might readily so contaminate the test-hole as to indicate considerable ore throughout several feet of the hole. On the other hand, holes or wells 30 to 36 inches in diameter are of such a size as to readily expose a sufficiently large surface as to show conclusively the presence or absence of workable ore in that immediate locality. It is obvious, however, that test-pits cannot be employed to advantage in other than residual deposits of clay and sand owing to the expense of sinking numerous large openings in hard formations. Test-pits to be effective in testing

ground for the irregular forms of deposits should not be spaced farther than fifty feet apart and in deposits lying closer to the surface an even closer spacing is desirable. With considerable depth of overburden the expense of sinking pits close together may be prohibitive and the distance between holes may have to be made seventy-five to one hundred feet. The disadvantage of spacing holes considerable distance apart may be largely overcome by running drifts from the pits, beginning at points where there are more or less pronounced showings of manganese on the walls.

The work of testing by pits is largely done by contract, the usual price being forty to fifty cents per foot; fifteen to twenty feet per day being common. Two men are employed; one at the surface to operate the windlass, the other working in the pit. The equipment, aside from a windlass, is a short-handled pick and shovel, a wooden pail serving as a receptacle for the loosened clay, sand and occasional boulder.

The testing of a deposit depends largely upon the lay of the ground; if of slight slope, test-pits can be employed to advantage, but if on a moderate or high slope, drifts can be used to better advantage. Owing to the irregularity of the deposits, both vertically and horizontally, the direction of the test opening is of little or no importance, either serving equally well in proving a deposit.

Trenches, while being useful in determining the depth of overburden, do little more than indicate the presence of manganese, the extent of the deposit remaining unproven. It is only by pits or drifts placed reasonably close together that even an approximate estimate of a deposit can be arrived at.

Development Work.—The development or opening of a manganese deposit depends largely upon its size, but probably more largely upon the thickness of the overburden and the slope upon which the deposit is situated. Deposits occurring near the surface with but little cover are preferably mined by open-cuts, while those lying at depths must of necessity be worked by underground methods.

Open-cuts are usually developed by making a cut into the bank, beginning at a point determined by requirements of handling the excavated materials, and maintaining a uniform level grade in order to facilitate handling of wheelbarrows or cars, also to permit the escape of water, especially after heavy rains. All excavated materials are handled through the cut; the waste going to the waste bank, the wash-dirt to the screening yard if dry mining is done, or to the washer if

the ore is to be washed. Occasionally open cuts are developed by drifts and inclines or slopes, where considerable barren ground has to be traversed before mining can be done. The advantages of open cut work are naturally such as result from having plenty of light, fresh air and greater facilities in handling excavated material; however, there are serious drawbacks to surface work, as excessive heat in summer and cold in winter, and loss of time due to bad weather. The

FIGURE 3. Open cut at the Hambright mine, showing massive body of ore in residual clay.

capacity of open cuts is large, as ample room may be had for developing the working face at the bank.

The development of underground deposits depends largely upon the form of the deposit, but also upon the lay of the ground. On slopes, drifts are most convenient and economical both with respect to forming and operating. Deposits lying on hillsides of moderate inclination can often be opened to advantage by shafts, but shafts should be employed only where drifts are impracticable, owing to distance that they would have to be driven, as the expense of operating shafts especially by hand is rather high; further, the capacity of shafts is small.

Shafts for the development of manganese deposits are small in size, seldom exceeding four by five feet inside dimensions, a more usual size being three and a half by four feet, or four by four feet. Shafts are occasionally lined with a crib-work of timber and less frequently

sawed timber and plank are employed, but probably in the majority of cases the clay walls are sufficiently firm and permanent to stand until the deposit is exhausted.

The sinking of shafts is usually done by day labor rather than by contract. Three men are usually employed, two operating the windlass and one loosening the dirt and filling the bucket. The cost of shaft sinking varies somewhat according to locality, but probably ranges from $1.50 to $2.50 per foot; when the shaft must be lined and timber can be had on the property the combined cost varies between $1.75 and $3.00 per foot.

Ordinarily in mining work the development of an ore body or mineral deposit is divided into two distinct operations, namely, connecting the deposit with the surface and providing passages within the deposit for the movement of men, the handling of supplies and ore, and for ventilation. While all of these operations are necessary in mining manganese, yet the restrictions and limitations previously noted in connection with other operations and arising from the irregularity of deposits, also affect the development work. The opening drifts often constitute both outside and inside development work, and at the same time merge into the strictly mining operation or the extraction of the ore or wash-dirt.

Mining.—Mining proper or breaking down of the ore is accomplished at the face of a bank in the open-cut, and at the face of a drift in underground work.

Open-cut work may be done by hand or by mechanical excavation, as steam shovels and drag-line scrapers. Hand work is largely limited to small-scale operations, also to moderate height of bank and amount of overburden that must be handled. Steam shovels, on the other hand, are adapted to large-scale operations, can excavate much higher banks than can be operated by hand work, and can economically strip with ease considerable depth of overburden.

Trucks for steam shovel work in manganese mining are usually provided with broad-faced wheels which operate on a bed or bulkhead of heavy timbers rather than the flanged wheels that must be provided with sectional track. The advantage in this equipment is that the shovel can be handled much more readily on soft ground than if it operated on sectional rail track.

It is rarely ever necessary to employ powder in breaking down banks in open-cuts, as the clays and sands are usually sufficiently

soft to be readily excavated by shovels. High banks are seldom carried in steam shovel work, although occasionally heights of 35 to 55 feet have been observed.

The drag-line scraper has been employed in a number of localities in the southern manganese fields, particularly in the Crimora Mine in Virginia and the Flint Springs property in the Cleveland district, Tennessee. In the former locality it was discarded as a failure, but is being used fairly successful in the latter locality. It is probable that the location of the drag-line with respect to the deposit is a determining factor in the success or failure of the equipment; a deep pit imposes rather severe conditions on the drag-line and at the same time limits its range of usefulness.

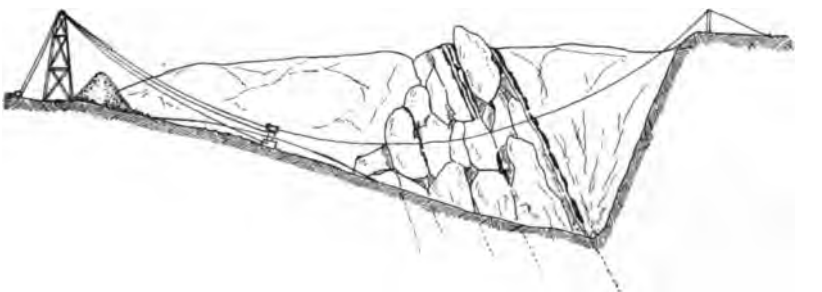


FIGURE 4. Use of drag-line scraper at Flint Springs mine, Tennessee.

A drag-line consists of a large drag scraper operated by cables. The scraper is attached to a two-wheeled trolley that travels upon a cable supported by towers at either end of the cut being excavated. Both carrying and traction cables are connected directly with the drums of hoisting engines; the former being raised and lowered by winding it up or unwinding it, thus permitting the trolley to be placed in any desired point in the pit and in line with the towers; the latter drawing the scraper forward and filling it, whereupon it is raised by tightening the carrying cable and transferred to the point of delivery through the medium of the traction cable. While the ground covered by the operation of the drag-line is limited to an area of a few feet in width between the towers, the range in depth is great and by shifting the end of the carrying cable considerable ground can be covered laterally. There is no doubt but that in certain localities the drag-line can be operated to advantage and can excavate ground even more economically than a steam shovel.

Underground mining operations are much more limited in extent than are the surface workings or open-cuts, as the least amount of work possible is done in order to secure the available ore. All work done by means of drifts is directed toward the one object of removing ore or wash-dirt, and as soon as the ore deposit is exhausted at one point, work is begun at another point where there is promise of ore occurring or where ore already exists. The work of mining ore is carried on entirely at the face of the drifts and is, therefore, what is commonly called breast stopping. In small irregular deposits it is possible to remove all of the ore to the height of a drift by drifting, but in wider deposits it is necessary to widen the face by skirting along the sides of the first drift driven. When it is found necessary to employ supports for the drifts, as is the usual practice, the sides of the skirting drifts are in turn supported by jam-sets, which are ordinary sets jammed up against the sets of the opening drift. An ore body equal in width to six or eight sets can readily be mined by the employment of jam-sets.

When an ore body is found to extend above the level of the opening drift, a second drift can be run, removing the ore to the height of another set; the sets of the second set being placed above and stand directly upon the caps or lagging of the sets below. Sets to the number of five to seven can be superimposed one upon the other, permitting a similar number of drifts to be driven and an ore body removed to a height equal to that number of sets, or from 35 to 50 feet.

In the case of a deposit extending below the level of the opening drift, the most satisfactory method of procedure would be to run a drift directly beneath the drift exposing the ore, placing the posts of the sets of the undercutting drift directly under the sills of the drift above.

It is evident that in the use of over- and under-cutting drifts, also in skirting operations, especially in such unstable formations as clays and sands, that great care must be taken, otherwise too extensive operations would subject the workings to danger of serious falls of ground. Loss of considerable portions of the workable deposits as well as danger to miners would result from such collapse of working places.

Large deposits with fairly solid and firm walls of inclosing clay could undoubtedly be worked to advantage by means of special methods that have found extended application in the mining of soft and

broken formations. The milling method could be employed in large deposits and especially in deposits situated on hill and mountain slopes of considerable inclination, where drifts and tunnels could be employed in developing them. From the line of the opening drift, passages or raises are driven, connecting with the top of the deposit or the surface, all excavated material passing through the raises to the drift below, where it is loaded into cars and disposed of according to its value. Such a method could be employed to advantage where there is little or no overburden, although considerable thickness of cover could be readily handled through the raises; with considerable depth of cover, the raises should extend to the top of the deposit only and provision be made for supporting the cover by the employment of specially constructed supports.

Mining the blanket deposits varies considerably from similar work in irregular deposits and resembles more closely work in bedded deposits such as coal and iron ore. Drifts run on such deposits must of necessity be very irregular, which renders the mining and handling of the ore very difficult. For workings of several hundred feet in extent, shafts could probably be employed to greater advantage than drifts and slopes; however, slopes are occasionally employed. Further, mining the blanket deposits entails handling of much waste and probably considerable more than in similar work with the irregular form of deposits, as the ore is more compact and consequently the volume is proportionately smaller.

The rhodochrosite ore at the East Fork Mine has been mined up to the present time by drifts, driven on the mineralized zone. While fairly satisfactory work can be done by drifts in the preliminary work of opening such a deposit, the milling method would be much more applicable for more extensive operations and large outputs.

Other operations incident to mining work, such as drainage, ventilation, lighting, etc., are simple and ordinarily present no serious nor complicated problems. The looseness of the deposits of residual materials readily permits of the escape of water that usually causes much trouble in mining operations. Rarely ever is any trouble experienced due to the accumulation of water in underground workings, but in open-cut work the bottoms of the pits often become puddled by working upon them, especially during wet weather, in which case water may collect, and, unless the pit is self-draining, must be pumped out. Candles and aceytelene lamps are commonly employed in under-

ground work; in open-cut work no lighting is necessary except when work is done at night. Aceytelene flare-lights may furnish ample illumination under such circumstances. Ventilation is usually a matter of small concern owing to the limited scale of the operations, but with more extended work some positive means of forcing air into the workings must be adopted; for shaft work "sails" can be used to advantage, furnaces are quite satisfactory for moderate length of drifts, but rotary blowers must be employed for workings of con-

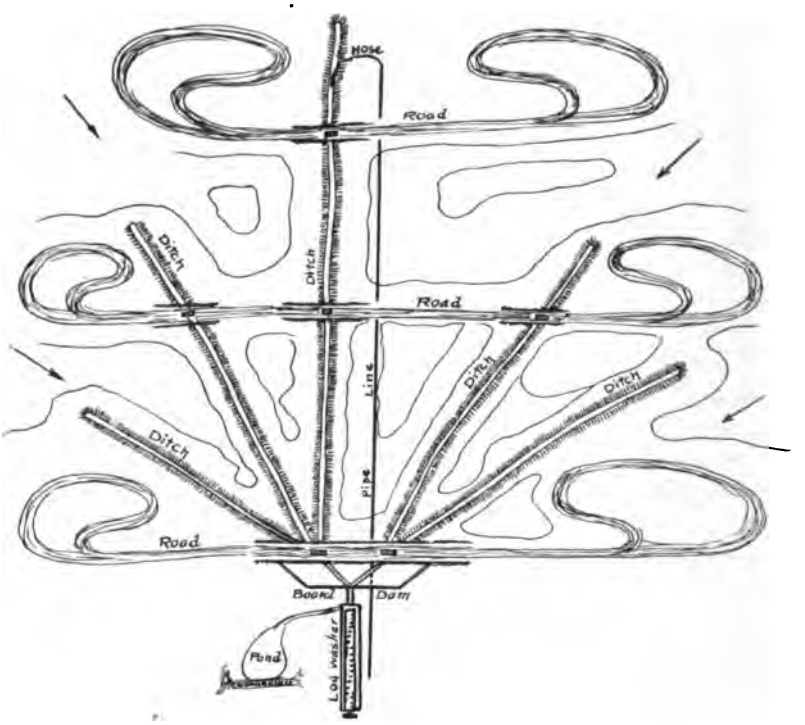


FIGURE 5. Sluicing method used at Unaka Minerals Company mine, near Louisville, Tennessee.

siderable extent. Small blowers, driven by a hoist and acting only while hoisting is being done, may prove satisfactory, otherwise a small gasoline engine may have to be employed.

Handling the ore or wash-dirt and waste from underground workings and strip pits, is an important part of the mining operations and varies largely with the methods of mining employed. In open-

cut work the excavated materials are largely handled in wheelbarrows operating on plank tracks or run-ways. All small scale operations employ wheelbarrows, and occasionally they are handled on fairly steep grades by two men, one pulling by rope, the other pushing. It is needless to say that such a method of procedure is both inefficient and expensive. Cars are employed in connection with steam shovels, being moved by hand and mules and occasionally by dinky locomotives. Owing to the practice of following deposits downward within the pit, considerable depth of pits often results, thus requiring the waste and wash-dirt to be hauled up grades of varying degrees of steepness. Locations of deposit may render it impossible to maintain a level or outward sloping approach and entrance to the pits, but where possible such arrangement should be employed. Dragline scrapers have an advantage over steam shovels in that they have the combined ability to excavate and transport, and do not have the disadvantage of maintaining tracks within the pits, which is often a difficult task.

Sluicing methods may be employed very satisfactorily where the slope is sufficient to move the dirt readily, and where an ample supply of water is available. Large tonnage of wash-dirt can be handled economically by sluicing and there is an added advantage in that clayey ore can readily be broken up and largely freed from adhering clay by passing through a sluice, of moderate length. The sluices are either wooden boxes or ditches formed in the clay bed, and are fed by dirt brought in wheelbarrows or by scrapers, and dumped into the sluices by hand or through a hole in a bridge.

Preparation of Manganese Ores

By W. R. Crane and E. R. Eaton.*

The methods employed in cleaning and concentrating manganese ores and the scale of the operations depend largely upon the size and character of the deposit worked. The forms of deposits previously outlined give some idea of the difficulties that may be experienced in their treatment. The irregular forms of deposits are commonly worked and produce the bulk of the material that is washed and otherwise treated. The other forms of deposits, while often large and of fair grade, have been largely ignored up to the present time, owing to the fact that certain more or less difficult problems are presented.

The principal difficulty arising from the treatment of ore or wash-dirt obtained from the irregular forms of deposits, is the uncertainty of a regular and uniform supply. Next in importance to the supply is the character of the manganese occurring in the wash-dirt and the relative proportion of mineral to waste. The forms of ore best adapted to washing and concentration is the nodular and pebble ore of small size, following which is the granular form, both of which are usually of convenient size for log washer and subsequent jig work. The kidney and dornick forms require reduction before they can be successfully handled by logs and on the picking belt, but owing to size and purity it is often possible to make a high percentage extraction prior to treatment in the logs and on the jigs of a standard washing plant.

Owing to the variable conditions mentioned there is a tendency to reduce the equipment employed in treating manganese to a minimum both with regard to kind and number of parts employed, which is frequently done irrespective of the desirability of limiting the necessary equipment. Poor and imperfect cleaning of ores and excessive losses usually result from the curtailment of equipment. It is, therefore, the object of this paper to give the layout of a standard washing plant, to describe the construction of the apparatus or machines, and to explain the operation and adjustment of the various parts.

*The field work on this report was done under a co-operative agreement between the State Geological Survey and the U. S. Bureau of Mines. The report is published by permission of the director of the U. S. Bureau of Mines.

The preparation of manganese ores may be divided into two separate and distinct methods, namely: dry-mining and washing or concentration.

Dry-mining.—Dry-mining does not refer to mining, but rather to the cleaning of the ore, and consists of screening the ore as it is mined. Not all ore or wash-dirt is adapted to dry-mining or cleaning by screens, as certain clays are wet and sticky or plastic, or may occur in large masses, rendering the separation from the ore by screens practically impossible. Dirt most suitable for dry-mining methods is dry and granular, breaking up readily and separating from the mineral with little or no effort.

With certain forms of deposits as the blanket and bedded forms, especially when the deposits have been broken up and distributed throughout beds of clay, hand work with or without screening may be profitably done, but even where the bulk of the ore is of fair size, considerable loss occurs.

The amount of manganese in the dirt is, however, the controlling factor in dry-mining; dirt having less than 15 per cent of mineral cannot be successfully separated by screening, unless the bulk of the mineral is fairly large size.

Washing and Concentration.—The principal considerations affecting the employment of washing and concentrating methods in the treatment of manganese ores are: quantity of wash-dirt available; percentage of manganese in the dirt; and the water supply. While ore may be profitably mined and hand-picked under certain conditions of occurrence even where the proportion of mineral to clay is 1 to 50, that is 2 per cent, yet that is practically impossible where log washers and jigs are employed. Under ordinary conditions of occurrence of manganese in a deposit of clay and sand, it is doubtful whether successful work can be done where the proportion is lower than 1 to 35, while 1 to 10, or 10 per cent, is a fair average of wash-dirt treated.

The cleaning of manganese ores as practiced in the Cartersville district, Georgia, is considered standard, owing to long use, and is largely followed in other districts. Rarely, however, are plants constructed and fully equipped with the apparatus that has proven useful and satisfactory in their operation; the practice cannot, therefore, properly be considered standard. Few plants have a full installation of essential apparatus, many have only a partial equipment, while a

number are operating with the irreducible minimum of equipment, namely: a log washer.

In order that an idea may be had regarding a proper method of treatment for the usual run of manganese-bearing dirt and clay, the following outline or flow-sheet is given:

WASH-DIRT TO 1.

1. Grizzly, 2 to 4 in. spaces between bars; oversize to 2; undersize to 3.
2. Rock dump.
3. Log washer, double logs, 20 to 30 ft. long; discharge to 4; overflow to 5.
4. Revolving screen, cylindrical or conical, perforations or meshes 1-2 and 3-16 in.; oversize, everything above 1-2 in. to 6; undersize, 1-2 to 3-16 in. to 7, 3-16 to 0 in. to 8.
5. Mud or settling pond.
6. Picking belt; rock to 2; manganese to 9.
7. Rougher jig (4 cells); grate discharges to 9; hutches, 1st to 9, 2d, 3d and 4th to 10; overflow to 5.
8. Sand jig (3 cells); gate discharges to 9; hutches to 9 or 10.
9. Finished ore bin.
10. Cleaner jig (3 cells); gate discharges to 9; hutches to 9 or 11; overflow to 5.
11. Shaking table; finished product to 9; overflow to 5.

There are seldom more than two jigs employed in the washing plants for manganese-bearing clays and sands, while in many plants only one jig is used. Revolving screens or trommels are commonly used, but many flat screens are employed; in either case it is the exception rather than the rule to find more than one size of opening, which ranges from ¾ to 1 in. The widest range of sizes fed to the jigs from such screens renders good separation next to impossible. Few of the products of the jigs are clean and require extensive hand picking to complete the preparation, while by simply running the hutches of the rougher jig, fairly clean products can be made on the second or cleaner jig. When only one jig is employed few of the products are suitable for market. Fairly close sizing as indicated in the flow-sheet would make a great improvement in the work done by jigs and reduce the expense of preparation of ore by eliminating hand picking.

A standard washing plant as given in the above flow-sheet is what may be called a single washer or unit, and has a capacity of 40 to 50 tons of clean ore per 10 hours. An increase in capacity of such a plant aside from a small increase gained through crowding, would

mean a doubling, trebling or quadrupling of the equipment, with corresponding increase in volume of wash-dirt treated. By single washer is not meant a single log, but a single plant with a double log; while single logs do good work, yet in the plant as outlined a double log should be employed.

Details of the construction of the various forms of apparatus or equipment as employed in a standard plant are given, in order that those unfamiliar with such apparatus may be able to understand them.

The rough sizing apparatus or grizzly situated at the level of the open-cut or mine, receives the wash-dirt by cars, scrapers, sluices or wheelbarrows and delivers it to the log washer, largely freed from large masses of rock. The size of the grizzly depends upon the means employed in handling the dirt; if fed by cars loaded by steam shovels the size must be considerably larger than when fed by hand or other means.

Grizzlies are made in a number of ways but differ mainly in kind of bar used. The most common form is made of railroad rails, laid flange up and parallel with the logs below. There are usually five rails spaced 4 inches apart, making 4 spaces; the length of the grizzly is 3½ to 6 feet. The rails are supported by heavy cross-timbers and are spaced by wooden or iron blocks, or are set into notches cut in the supporting timbers; they are usually held securely in place by timber bolted down upon their ends. The wash-dirt is sorted upon the grizzly, the clay and sand falling through together with all small pieces of manganese and rock; the larger pieces of rock are removed and sent to the rock dump, while the larger pieces of manganese are broken up and forced through the grizzly. Enclosing the grizzly is a wooden box or hopper made of plank, which receives and holds the wash-dirt until fed through the bars.

Logs are undoubtedly the most important part of a washing plant, as they handle large quantities of wash-dirt of a wide range in character and do very efficient work in removing the clay and sand. A double log washer consists of a long strongly built box or trough standing at a slight inclination longitudinally, in which are mounted two long timbers or logs. The logs are provided with gudgeons at the ends, which consist of journals and flanges, the flanges being bolted to flanged octagonal sockets fitting over and fastened to the ends of the logs. The logs are connected by gears at the upper ends, being driven by a train of beveled gears, which in turn are driven by belt.

The trough is constructed of 2-inch plank placed longitudinally, being firmly held in place by frames of heavy timber. The ends of the trough may be made of plank or cast iron plates, the latter having flanges to which are bolted the side planks. The lower plate is called the back gate, the upper the front plate, both of which contain the bearings or pillow blocks. The front plate also has an outlet or discharge opening for the washed mineral, being placed centrally in the plate. The slope of the logs ranges from ¾ to 1½ inches per foot.

The logs are octagonal in section and range from 16 to 18 inches in diameter between parallel faces, which are protected by straps of iron 2 by ¼ inches and serve as supports for the blades. The blades are 4½ inches wide, 1 inch thick and about 8 inches long. They are put on in two rows in the form of screw-threads, eight blades to the circumference of the log. If the pitch of the threads is 5 feet, which is common, it is necessary to advance each blade 7½ inches for each one-eighth turn or for each side of the octagon. The ends of the blades are of chilled cast iron and are set at angles of 30° to 45° depending upon the character of the material treated; for tough clays the angle should be small, for clays that are easily broken up the angle should be greater.

The logs are set so that the blades of one pass between those of the other, which can readily be secured by setting the log so that when geared together the two oppositely placed blades at the upper end of one log stand vertically, while those on the second log lie horizontally. The action of the blades is such that when the logs revolve the lower blades at the bottom of the trough approach one another, the sloping faces of the blades pushing forward any hard material as rock and ore that they come in contact with. The lifting and pushing action of the blades forcing the ore and clay up the sloping bottom of the trough, together with the thorough agitation in a stream of wash water flowing against the upward moving material, is responsible for the thorough washing done by logs.

The number of revolutions of logs varies from 12 to 15 per minute; the amount of water required varying from 50 to 75 gallons per minute; the capacity is 40 to 50 tons clean ore per ten hours; and the horse power required to drive double log ranges from 20 to 25.

The revolving screen is next in order after the logs and is intermediate between logs and jigs as washing and cleaning apparatus. It consists of a cylindrical or conical surface of woven wire or per-

forated metal mounted on suitable supports to maintain the shape of the screening surface, the whole being supported on and rotated by a shaft. The screening surface should have at least two sizes of openings, each occupying about one-half the length of the screen. The sizes best adapted to manganese washing are probably $\frac{3}{16}$ inch for the smaller and $\frac{1}{2}$ inch for the larger openings or mesh.

The screening surface is either bolted or rigidly fastened to cast iron wheels by hoops that are tightened by bolts. The wheels are keyed to the driving shaft and spaced at frequent intervals in order to properly support the screen, preventing sagging and reducing vibration. An inclination of 10° to 15° should be given the screening surface in order to cause the material to pass promptly through the screen.

Revolving screens are driven by gearing, chain and sprocket, and occasionally by belts, direct from the logs or log gearing. The usual number of revolutions for screen of 36 to 48 inches in diameter is 15 to 20 per minute. The capacity of screens of the sizes given ranges between 45 to 55 tons per 10 hours for the smaller and 50 to 75 tons for the larger. The proper length of screens is 60 to 72 inches.

The over-size material from the revolving screen passes to a picking belt, where the coarser material, passing through the logs, is finally separated, the ore going to the finished ore bin while the rock goes to the rock dump. While there are a number of different kinds of picking devices, the most satisfactory is the rubber belt, which serves both as a conveyor and a picking belt.

The sizes of picking belts commonly employed in manganese plants that have proven satisfactory for the usual range of work done are: 30 feet long by 18 inches wide to 50 feet long by 30 inches wide. The capacity of picking belts is limited by the character of the work done; if the material sorted is largely ore and the waste rock is fairly coarse, the capacity is large; similarly where the percentage of ore is small and the individual prices are large, but where the ore and waste are about equal in amount and there is a wide range in sizes, the capacity may be small.

Jigs are employed in handling and treating the undersizes from the screens. There should be at least two sizes, one for the coarser and two of the finer work. The first or coarse jig is called the rougher, the next treating the smaller of the undersize material is known as

the sand jig, while the third of the same size as the second, and treating products from both the rougher and sand jig, is the cleaner jig.

The type largely used in manganese cleaning is the Harz jig, being commonly known as the Joplin and stepped jig. The jigs should have at least three working compartments, while the rougher would operate to better advantage with four compartments. The jig box is built in a number of ways, but probably the most satisfactory is to use 2 by 4-inch lumber, which while being easy to put together may also do away with the heavy enclosing frames required by other methods of construction. Compartments are formed in the jig box by building partitions transversely, thus dividing the box into portions of equal dimensions. The compartments all in turn partly subdivided by partitions extending downward from the top of the jig box to a point about one-half the height of the box. Each compartment is thus formed into a U-shaped passage, one part or arm of the passage being of greater height than the other mainly to provide support for the drive shaft, also to furnish a higher head of water in that part of the passage than in the other; the compartment of greater height is known as the plunger cell, the other the screen or sieve cell.

In ordinary practice the plunger and sieve cells are of the same size, although variations are found; however, in the construction of the jig box it is preferable to make them of equal size and to reduce the cross-sectional dimensions, if desired, by placing lining boards on the walls of the plunger cells. The size of compartments may be the same for all three jigs and varies from 20 to 24 inches wide by 30 to 38 inches long for sieve cells, to 18 to 22 inches wide by 30 to 38 inches long for plunger cells.

The sieve cells or the front compartments of a jig have considerably less height than the plunger or back cells; the tops are also placed at lower levels, beginning at the head or feed end of the jig box and proceeding toward the opposite or tail end. The object of this systematic reduction in level is to permit a flow of water and feed from one compartment or cell to the adjacent and lower one. Screens are placed in the cells, the level of each conforming with the height of the various cells.

The plunger cells are provided with plungers supported and operated by heavy iron rods passing through the center and clamped in between heavy cast-iron washers by nuts. The plungers are held closely in position and are positive in action. The upper ends of the

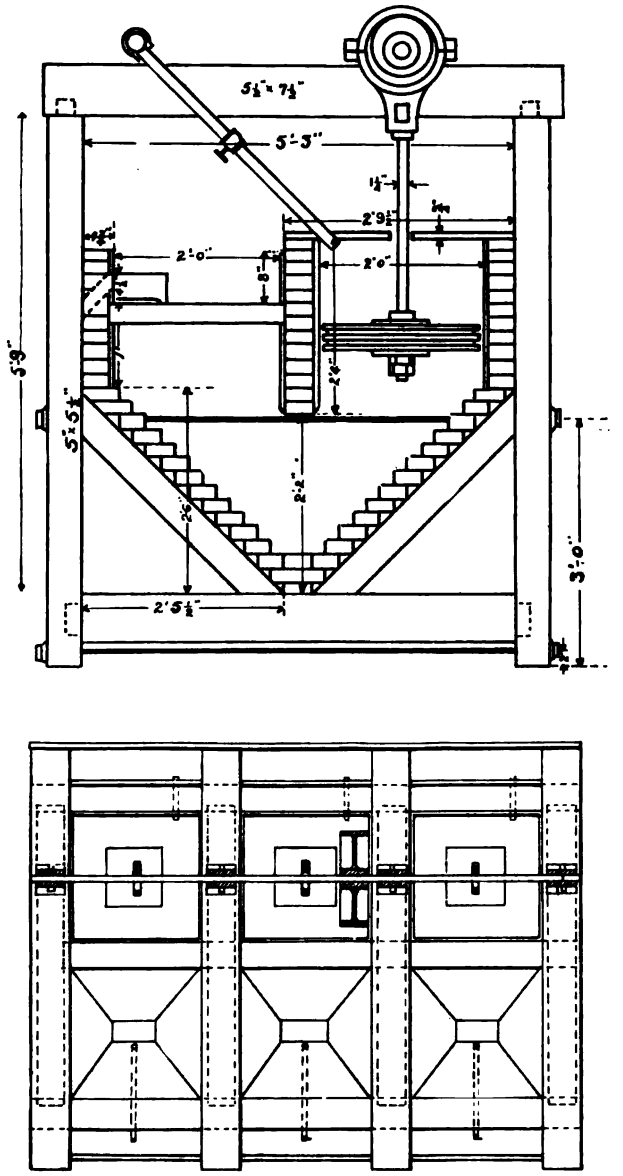


FIGURE 1. Top and side view of Harz jig, which is commonly used in manganese cleaning.

plunger rods are screwed into the shanks of cast-iron eccentrics, which are in turn keyed rigidly to the driving shaft. The eccentrics should be of the adjustable form and with sufficient range in adjustment to permit proper setting to do good work. The usual and desirable range of adjustment is from 3/4 to 2 inches, but if larger sizes are treated than given for work in a standard plant, a greater length of stroke should be provided for in the eccentrics.

The speed of drive shafts should be 150 r. p. m. for the rougher jig, and 200 for the sand and cleaner jigs. The length of strokes for rougher jig is 1½ inches for the first two plungers and 1¼ inches the last two, while 1 inch and 7/8 inch are suitable for the first two and last two cells of the sand and cleaner jigs.

Screens or sieves for the front cells are of two kinds, namely: cast-iron and wire cloth. Cast-iron screens are largely used in jigs treating coarse sizes and have the advantage that they are rigid, self-supporting and easily replaced when broken or worn. There is, however, greater variation in size of openings in cast-iron than other screens owing to difficulty in casting. Wire screens are widely used particularly with the smaller sizes of mineral treated, but are fiexible and must be supported, which is accomplished by placing wooden supports in the sieve compartments and fastening the screens to them. The wooden support consists of strips of soft wood set on edge and extending longitudinally in the cell, or when fine mesh cloth is employed cross-pieces may be employed forming a cell-work of wooden strips, thus giving support in all directions. The size of mesh of screens for the different cells should be varied somewhat to suit the size of material fed to the jigs, but when jigs with only a few cells are employed there is less need of a change in size. The following sizes of openings or mesh of screens should be employed in the three jigs of the standard plant: rougher jig 1/4, 1/4, 3/16 and 3/16 inch for the four cells; sand jigs, 3/16, 3/16, 1/8 and 1/8 inch for the four cells; cleaner jigs same as sand jig.

The bottoms of the jig box between the transverse partitions are formed into hoppers by sloping bottom boards, the apexes of the inverted pyrimidal spaces being at the front of the jig or in the middle of the compartment, depending on how the material collected in the bottom of the jig boxes is handled; if drawn off from the front, the former arrangement would be employed, if from the back of the jig, the latter arrangement is preferable. Openings made in the walls of

the jig box and connecting with the several compartments are provided with gates, usually of the sliding or rotating types, which are operated by a long-handled lever, permitting both quick and positive action in opening and closing the passages. When materials are drawn from the rear of the jigs, the bottoms of the hoppers are often provided with pipes that extent from under the jigs to some convenient position and are equipped with gates or valves to control the flow. The gates or valves are called spigots and the products discharged are known as hutches.

Mineral accumulating on the sieves consists of two parts, namely: the heavy manganiferous portion not readily moved except downward by gravity, and the lighter portion made up largely of quartz. The latter is displaced in the bed by the former and as soon as it reaches the height of the enclosing walls of the sieve cells is washed off by the flow of water from one cell to the next lower and thence over and off the jig. The former must be removed either by scraping aside the lighter minerals lying above them, or by drawing it off through the walls of the jig. Each sieve cell has, therefore, an opening cut through the front wall, which is provided with a gate and dam to control the discharge of the coarse concentrates accumulating on the sieves. The gate is a strip of sheet iron placed on the inside of the front wall of the jig and adjustable by vertical movement so as to regulate the size of opening. The dam consists of a half-cylinder of sheet metal also placed on the inside of the front wall of the jig and adjustable; further the dam encloses the gate. The dam is set at the desired height above the sieve and determines the character of the mineral reaching the gate. The lower edge of the dam must stand in the material to be discharged and as clean manganese is discharged the height should be from 1½ to 2½ inches.

The water entering with the mineral is called feed or carrying water and should be sufficient in amount and clear, in order that the action of the jig may be observed, therefore it is the usual practice to add fresh water to the feed just before it enters the jig or at least in the feed launder. Often this additional water is ample in amount to supply the jig and at the same time to provide for wastage. However, when the hutch is being discharged from the bottom of the jig, it may be necessary to add to the water in the jig by introducing water into the body of the jig either above or below the plungers. A pipe may be run above the jig and longitudinally with the jig, or back

of the jig box, connection being made by branch pipes to the plunger cells. The water fed to the jig in this matter is called hydraulic water. The size of the main hydraulic water pipe should be 2 inches, the branches 1 inch. The amount of water used by four cell jigs is about 350 to 400 gallons per minute, for three cell jigs proportionately less.

Height of dams or tail boards between sieve cells should be 3½ to 4½ inches, which determines depth of bed; increased depth of bed means a corresponding increase in length of stroke plunger. The drop between adjacent cells should be about 1 inch.

Briefly stated the movement of wash-dirt through a standard plant or washer is as follows:

Dirt from the mine is thrown upon the grizzly where all coarse material is separated out and sorted according to its value, the rock going to waste pile, the coarse manganese being broken up so that it can pass through the grizzly and go to logs with all fine material. Water is frequently used to facilitate the movement of dirt through the grizzly, but is applied particularly to the finer material that has passed the grizzly.

The grizzly being placed above the logs feeds directly on or between them, falling into the water filling the log box or trough. The rotation of the logs causes the dirt to be thoroughly stirred and rubbed, and at the same time forces it up the sloping bottom of the trough to the discharge opening at the upper end; the blades acting both as agitators and propellers. The coarser material, including sands, gravel, nodules and fragments of manganese, and cobble stones, is discharged by the logs at the upper end, while clay and the finer particles of sand and waste leave the trough by way of the overflow at the lower end of the trough. Care must be taken with regard to slope of trough, speed of rotation of the logs, position and height of overflow, and amount of wash-water employed, which must be suited to condition and character of wash-dirt if satisfactory work is done.

The material discharged by the logs enters the revolving screen where it is still further washed and freed from adhering clay, and separated into three sizes; the oversize going to picking belt, the undersize to the jigs. The oversize is composed of all sizes above ½ inch. which can be readily sorted by hand. The undersize is divided into two portions: 0 to 3/16 inch and 3/16 to ½ inch, the former going to the sand jig, the latter to the rougher. The screen should be so operated that distinct grades of material are made, according to sizes given.

Care in the design and operation of the screen has much to do in the subsequent work of cleaning manganese, particularly in jigging.

Ample room should be provided for the handpickers working at the picking belt; good light and shelter from sun, rain and wind are important; further, facilities for disposal of sorted products is important, no accumulations of waste or mineral should be allowed. Width and length and slope of belt are important, but are determined largely by conditions existing at the plant, such as slope of ground and disposal of waste and mineral.

The undersizes from revolving screens go direct to the rougher and sand jigs where the final cleaning of the finer material is accomplished. The rougher jig should produce coarse concentrates above the sieves, also the first hutch product should be clean; the remaining hutch products should be retreated. The sand jig should also produce coarse concentrates above the gate discharges and probably clean products from the first two hutches, the remaining hutches being re-run with similar products from the rougher jig. The cleaner jig should produce coarse concentrates and clean hutches, but with ores containing considerable sand and iron it would be advisable to employ a shaking table in order to produce a high grade product.

It is also possible to effect a small saving from the overflow of the logs by screening out the coarser sizes and settling the finer size in classifiers, the coarse size going to the revolving screen, while the settled product is retreated on the shaking table.

No satisfactory nor economical treatment of soft or wad ore has been found as yet and it is doubtful whether such ores can be worked on a permanent basis, owing to high silica content.

Treatment of the breccia ores that are found in considerable quantities in portions of the manganese fields of Tennessee can be freed from their silica and other impurities by graded crushing and jigging, shaking tables being employed where the jig products still retain considerable silica.

The Coal Pyrite Resources of Tennessee and Tests on Their Availability*

BY E. A. HOLBROOK AND WILBUR A. NELSON.

INTRODUCTION.

The brassy yellow colored mineral pyrite (FeS_2), a combination of iron and sulphur often known as fools' gold, is of common occurrence in many kinds of rocks. Commercially it is important only as the basis for the manufacture of sulphuric acid, an acid essential in the manufacture of explosives, fertilizers and other chemical products. On roasting, the pyrite gives up its sulphur to form the gas, sulphur dioxide, which in turn is converted into sulphuric acid in large chambers, chiefly by the use of steam.

Formerly most of the pyrite used in the United States came from Spain, although some sulphuric acid was manufactured by burning or roasting pure native sulphur mined in Louisiana. At the beginning of the present war the Spanish supplies were cut off and it seemed essential, in view of the increased demand for sulphuric acid, to develop every available source of supply in this country. Many pyrite mines were opened in the Appalachian Mountains, especially in Northern Georgia; and increased attention was given to the sulphur deposits in Louisiana and Texas.

It is well known to those engaged in coal mining that frequently balls and bands of pyrite occur with the coal, and this impurity must be removed from the coal before it is placed on the market. Because the coal in a mine contains pyrite balls or bands, however, does not mean that the coal from this mine is high in sulphur, or inferior in quality, for often the contrary is true; that is, the sulphur, having concentrated into definite balls and bands, leaves the true coal comparatively free from sulphur.

Knowing that there were possible pyrite resources in certain of the coal mines in Tennessee, the State Geological Survey effected a co-operation with the United States Bureau of Mines, by which a

*This report was made in co-operation with the U. S. Bureau of Mines, through their Middle West Station, Urbana, Ill., Mr. E. A. Holbrook representing the government.

survey of the pyrite in Tennessee coal mines has been made, and favorable material has been tested in the laboratory used by the Bureau of Mines at Urbana, Illinois.

At the present time, October, 1918, it appears the great demand for pyrite has been met, partly by an unexpectedly favorable development of new sulphur resources in Louisiana and Texas, and partly by development of pyrite mines in the Appalachian Region and in

FIGURE 1. Coal pyrite from the Bon Air district.

Canada. Also it has not been considered opportune to interfere in any way with the production of coal. For these reasons the demand for coal pyrite has not been as great as was expected earlier in the year. However, the supply known to be available constitutes a great reserve in time of need, and calls attention to a potential resource for the future.

This report outlines the known coal pyrite resources of Tennessee and details tests made at Urbana, Illinois, on crude pyrite from the mines of the Bon Air Coal and Iron Corporation, to learn if the material could be mechanically treated to produce a pyrite of commercial purity.

Coal Pyrite Resources in Tennessee.*

Outside of the large deposits of pyrite and pyrrhotite in East Tennessee in the Ducktown region, Tennessee has an additional source of pyrite from certain of the coal seams of the Cumberland Plateau.

The mines in the Bon Air-Clifty district all contain pyrite in the form of bands, nodules and kidneys, which are easily separated from the coal and can be recovered as a by-product. It is estimated that the daily tonnage of pyrite, if all is recovered, from the mines in this district when operating at full capacity will be at least fifty tons daily. This estimate was made to include all the mines operating on the Bon Air branch of the Nashville, Chattanooga and St. Louis Railway.

Clean samples of pyrite from some of these mines gave the following analyses:[1]

Carola Shaft, Bon Air, Tenn.	47.0 per cent sulphur
Braeburn Mine, Eastland, Tenn.	47.6 per cent sulphur
Ravenscroft Mine, Ravenscroft, Tenn.	46.4 per cent sulphur

The mines on the Monterey branch of the Tennessee Central contain pyrite in a recoverable form. This pyrite is similar to that from the Bon Air district, on which tests were made. It is estimated that probably forty tons of pyrite a day could be recovered from this district. Clean samples of pyrite were taken from some of these mines, which gave the following analyses:[2]

Fentress Coal Co., Wilder, Tenn.	46.4 per cent sulphur
Peacock Mine, Big Mountain Coal Co., Obey City, Tenn., Weathered surface pyrite	46.1 per cent sulphur

Hand cobbed samples of pyrite were also taken from these mines, so as to show the approximate percentage of sulphur in carload lots of unwashed pyrite as it would be shipped from the mines if no

*The paragraphs under this subheading were prepared by Wilbur A. Nelson.
[1]Collected by E. A. Holbrook, analyzed by U. S. Bureau of Mines.
[2]Collected by E. A. Holbrook, analyzed by U. S. Bureau of Mines.

plant for treating the pyrite was installed. The following analyses show these results[3]

Carola Shaft, Bon Air, Tenn.	43.88 per cent sulphur
Braeburn Mine, Eastland, Tenn.	46.40 per cent sulphur
Ravenscroft Mine, Ravenscroft, Tenn.	43.72 per cent sulphur
Clifty Mines, Clifty, Tenn.	42.72 per cent sulphur
Fentress Coal Co., Wilder, Tenn.	45.08 per cent sulphur
Peacock Mine, Big Mountain Coal Co., Obey City, Tenn.	40.36 per cent sulphur
Brier Hill Collieries, Crawford, Tenn.	36.08 per cent sulphur

The pyrite from the Fentress Coal Company has been shipped to an acid manufacturer for some time, with satisfactory results to both the mine owners and the acid makers. The pyrite from all these mines, with the probable exception of the Brier Hill Collieries, would be satisfactory for acid making after having been crushed and cleaned.

Pyrite is also found in a few of the mines in the Tracy City-Coalmont district, but not in sufficient quantities to justify saving and shipping.

In the northeastern Tennessee coal field some pyrite occurs, but no detailed investigation was made of this area.

Tests Made at Urbana, Illinois.

About September 1, 1918, two shipments of crude coal pyrite were received at the laboratory of the U. S. Bureau of Mines, University of Illinois, Urbana, Illinois, from the Eastland and Ravenscroft mines of the Bon Air Coal and Iron Corporation, of Bon Air, Tennessee. The possibilities of utilization of coal pyrite on a large scale for the manufacture of sulphuric acid made it desirable to conduct tests on this material to learn if mechanical crushing and washing would produce a high grade commercial pyrite free from coal and other impurities and with possibly clean coal as a by-product. The report following gives an outline of the final tests, together with a flow-sheet outlining a possible method of mechanically treating these materials.

MATERIAL FROM THE EASTLAND MINE.

This lot, about 500 pounds of crude coal pyrite marked from the Eastland mine, consisted of lenses of pyrite up to 10 inches in width and 4 inches in thickness, together with considerable adhering

[3]Collected by Wilbur A. Nelson, analyzed by the Chemist, State Geological Survey.

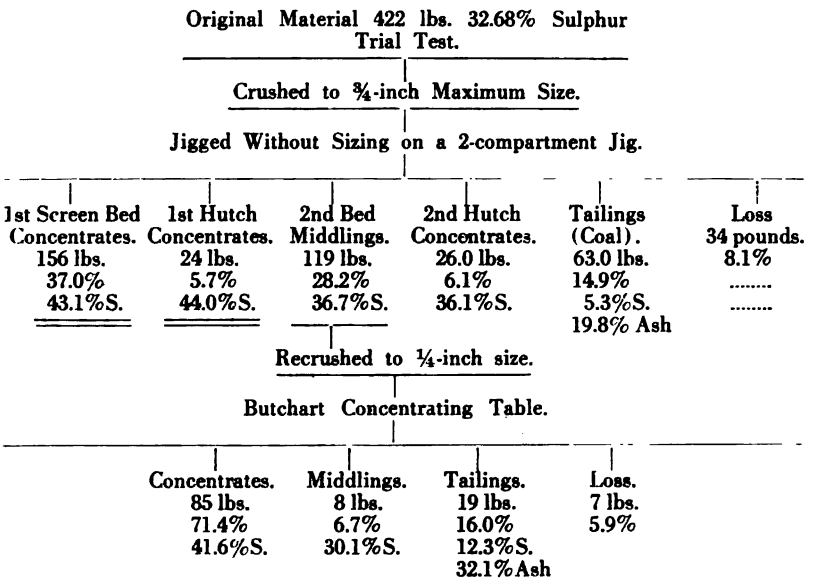
coal. To the eye, about 50 per cent of the lumps by volume was pyrite and the remainder was adhering coal.

Preliminary tests showed that the clean pyrite in the material was high grade, and that crushing to about 1-inch size would produce a clean pyrite concentrate, and consequently fairly clean coal as a by-product. During crushing, a comparatively small amount of pyrite fines were produced, and therefore the largest sizes were the richest in pyrite. In other words, this coal pyrite, unlike the usual pyrite mineral, is stony and amorphous in structure and does not slime on crushing. This very important point made it possible to recover most of the pyrite by* jigging alone, and the* concentrating table was necessary only in treating the recrushed middlings. Even this product might be fed into the jig and saved as a hutch product, providing the capacity of the jig was ample.

The accompanying quantity flow sheet (page 6) shows the results of the final test run on the pyrite from the Eastland mine. Four hundred and twenty-two pounds were crushed to ¾-inch size in a gyratory crusher followed by rolls. This was jigged in a 2-compartment Harz jig with ¼-inch screen beds. The coarse concentrates were saved as a screen bed product and the fine concentrates were saved as a hutch product. The second screen bed product contained some coal adhering to the pyrite and was a true middling product. It was therefore crushed through a ¼-inch screen and treated on a Butchart concentrating table. The table cleaned this product and produced a high grade concentrate.

*The jig and concentrating table are simple machines in common use in the preparation of minerals.

Flow Sheet of Coal Pyrite Concentration Material From Eastland Mine of the Bon Air Coal and Iron Corporation, Bon Air, Tenn.


Original Material 422 lbs. 32.68% Sulphur
Trial Test.
Crushed to ¾-inch Maximum Size.
Jigged Without Sizing on a 2-compartment Jig.
1st Screen Bed Concentrates. 156 lbs. 37.0% 43.1%S.
1st Hutch Concentrates. 24 lbs. 5.7% 44.0%S.
2nd Bed Middlings. 119 lbs. 28.2% 36.7%S.
2nd Hutch Concentrates. 26.0 lbs. 6.1% 36.1%S.
Tailings (Coal). 63.0 lbs. 14.9% 5.3%S. 19.8% Ash
Loss 34 pounds. 8.1% ....
Recrushed to ¼-inch size.
Butchart Concentrating Table.
Concentrates. 85 lbs. 71.4% 41.6%S.
Middlings. 8 lbs. 6.7% 30.1%S.
Tailings. 19 lbs. 16.0% 12.3%S. 32.1%Ash
Loss. 7 lbs. 5.9%

NOTES.—1st Screen Bed Concentrated means the coarse concentrates saved on the 1st bed of the jig.

2nd Hutch Concentrates means the fine concentrates passing through this screen and saved at the bottom of the jig.

Middlings means a product of pieces containing part coal and part pyrite which have to be crushed finer before any separation of clean pyrite can be made.

The Resume Sheet (page 66) shows the details of the run.

TESTS ON CRUDE PYRITE FROM THE RAVENSCROFT MINE OF THE BON AIR COAL AND IRON CORPORATION.

The crude coal pyrite from the Ravenscroft mine was of about the same physical appearance as the material from the Eastland mine.* Some of the lenses, however, were of rather light weight and had a peculiar gray color. To the eye it appeared about 75 per cent pyrite by volume and the remainder was adhering coal. This material was tested in a preliminary way and the tests indicated that the same treatment could be used as with the material from the Eastland mine.

*The pyrite which occurs in the mines on the Monterey branch of the Tennessee Central Railroad has the same physical appearance, and it is thought could be prepared for market in a similar way to the pyrite tested.—Wilbur A. Nelson.

This is a point of importance, because in any concentrating plant it would allow indiscriminate mixing of the material from the various mines before treatment. On crushing, the crude pyrite produced only a small percentage of fines, and it appeared that in regular practice, crushing to 1-inch round hole size would be sufficient before attempting concentration.

Resume of Run of Eastland Mine, Bon Air Coal and Iron Corporation.

Total, 422 lbs., 32.7% Sulphur.

Product	Concentrates		Middlings		Tailings		Loss
	Weight	Analysis Sulphur	Weight	Analysis Sulphur	Weight	Coal Analysis	
1st Bed Concentrates	156	43.1%	.....	.....	.....	.....	.....
1st Hutch Concentrates	24	44.0%	.....	.....	.....	.....	.....
2nd Bed Middlings (see Table Products)	.....	.....	.....	.....	.....	.....	.....
2nd Hutch	.....	.....	26	36.1%	.....	.....	.....
Jig Tailings	.....	.....	.....	.....	63	5.3%S. 19.8%A.	.....
Table Concentrates	85	41.6%	.....	.....	.....	.....	.....
Table Middling	.....	.....	8	30.1%	.....	.....	.....
Table Tailings	.....	.....	.....	.....	19	12.3%S. 32.1%A.	.....
Jig Loss	.....	.....	.....	.....	.....	.....	34 lbs.
Table Loss	.....	.....	.....	.....	.....	.....	7 lbs.
Totals	265	42.7%	34	34.7%	82	6.9%S. 22.6%A.	41 lbs.

Practically 265 lbs. of commercial pyrite were recovered, or 62.8 per cent of the total material treated. On further treatment, the 34 lbs. of middlings could be expected to yield 25 lbs. of commercial pyrite, making a total recovery of 290 lbs. of pyrite or 68.7 per cent. The coal tailings were 82 lbs., or 19.4 per cent. The treatment loss was 41 lbs., or 9.7 per cent.

The accompanying flow sheet (page 67) shows the final test treatment of the crude pyrite, together with the products, their quantity and analysis. The resume sheet (page 68 shows the various products and gives an idea of what might be accomplished in percentage of recovery, etc., in a commercial plant.

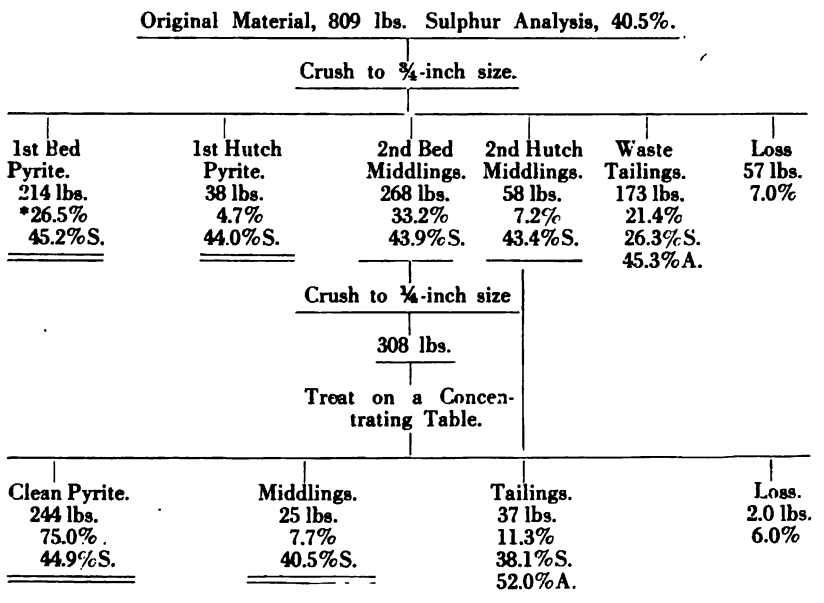
Conclusions.

The material from both the Eastland and Ravenscroft mines is high grade pyrite with only a small percentage of attached coal. There is no technical difficulty in crushing it to about 1 inch size and,

by jigging alone, to save nearly all the contained pyrite in a pure form. While the coal can be recovered in a size and purity such that it can be used as ordinary coal of screening size, yet if most of the pyrite contained as little coal as that sent for testing, it is not commercially important to save and clean the small amount of coal produced.

The concentrating table is recommended only as an auxiliary machine to clean the middling products. For a small plant the recrushed middlings could be fed back to the jig and a concentrating table dispensed with. However, this plan lessens the capacity of the jig.

Bon Air Coal and Iron Corporation, Mine Refuse From Ravenscroft, Tenn.


Original Material, 809 lbs. Sulphur Analysis, 40.5%.
Crush to ¾-inch size.
1st Bed Pyrite. 214 lbs. *26.5% 45.2%S.
1st Hutch Pyrite. 38 lbs. 4.7% 44.0%S.
2nd Bed Middlings. 268 lbs. 33.2% 43.9%S.
2nd Hutch Middlings. 58 lbs. 7.2% 43.4%S.
Waste Tailings. 173 lbs. 21.4% 26.3%S. 45.3%A.
Loss 57 lbs. 7.0%
Crush to ¼-inch size
308 lbs.
Treat on a Concentrating Table.
Clean Pyrite. 244 lbs. 75.0%. 44.9%S.
Middlings. 25 lbs. 7.7% 40.5%S.
Tailings. 37 lbs. 11.3% 38.1%S. 52.0%A.
Loss. 2.0 lbs. 6.0%

*26.5% means that 26.5 per cent by weight of the original material was saved here.

Resume of Test on Pyrite From Bon Air Coal and Iron Corporation, Ravenscroft, Tenn.

Weight, Less Sample, 790 lbs.

Product	Pyrite Recovered		Middlings		Coal Tailings or Refuse		Losses
	Weight	Sulphur Analysis	Weight	Sulphur Analysis	Weight	Analysis	
1st Bed Pyrite	214	45.2%	.....	.....	.....	.....	.....
1st Hutch Pyrite	38	44.0%	.....	.....	.....	.....	.....
2nd Bed Middlings (see Table Products)	.....	.....	.....	.....	.....	.....	.....
2nd Hutch Middlings (see Table Products)	.....	.....	.....	.....	.....	.....	.....
Jig Coal Tailings	.....	.....	.....	.....	173	26.3%S. 45.3%A.	.....
Table Pyrite	244	44.9%	.....	.....	.....	.....	.....
Table Middlings	25	40.5%	.....	.....	.....	.....	.....
Table Coal Tailings	.....	.....	.....	.....	37	38.1%S. 52.0%A.	.....
Jig Loss	.....	.....	.....	.....	.....	.....	57
Table Loss	.....	.....	.....	.....	.....	.....	2
Totals	521	44.7%	.....	.....	210	28.4%S. 46.5%A.	59

From 790 lbs. treated, 521 lbs. of pyrite were recovered, analyzing 44.7 per cent sulphur. This is a recovery of 66 per cent. The middlings were fine enough to be included in this pyrite column.

The coal tailings were 210 lbs., or 26.6 per cent of the original material. They analyzed 28.4 per cent sulphur and 45.6 per cent ash. This material is useless for coal on account of its high sulphur and ash content. Technically, there would be no difficulty in crushing this material finer and in extracting some of the remaining pyrite.

The treatment losses were 59 lbs., or 7.4 per cent.

On page 69 is a flow sheet of a proposed concentrating plant for the crude pyrite from these mines based on an estimated treatment capacity of 50 tons per 8-hour day. It should be remembered that on account of the low value per ton of the pyrite it is necessary to keep a treatment plant as simple as possible, and that while better recoveries might be made with a more complicated plant, yet from the tests it does not seem advisable to install expensive apparatus necessary if the small sizes were to receive special treatment. Moreover, the coal pyrite slimes very little on crushing, and the small sizes are the lowest in pyrite content.

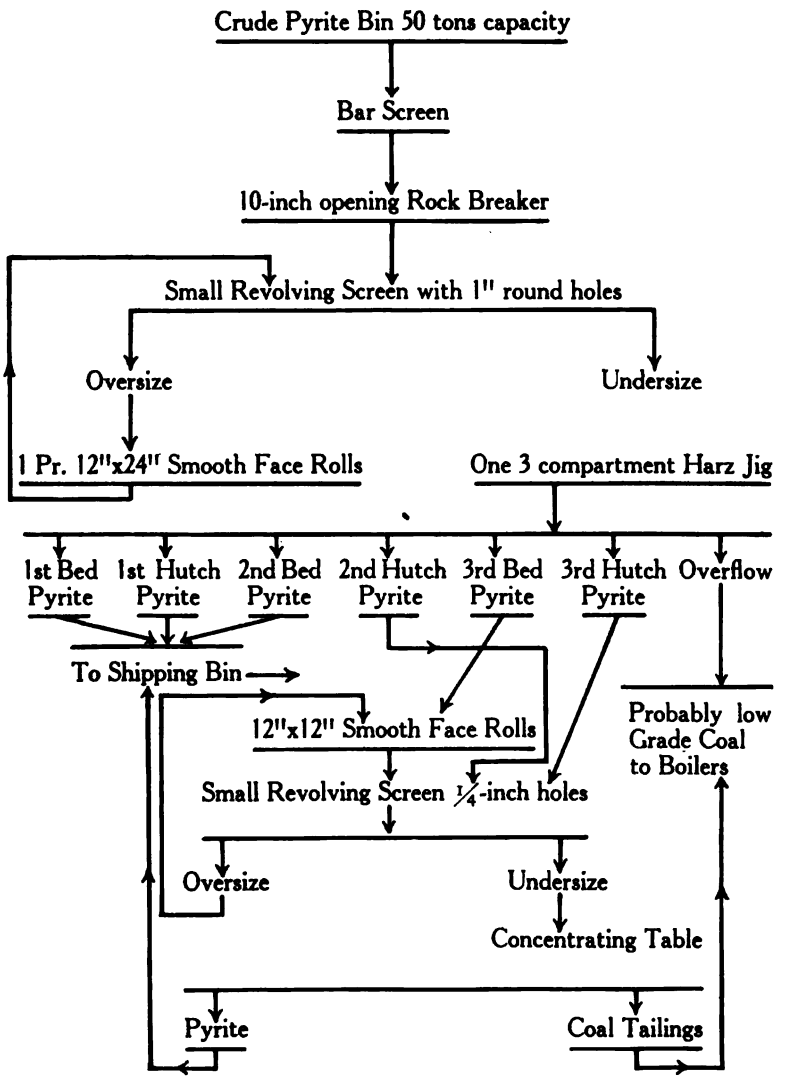
As a preliminary estimate, a plant to treat 50 tons per 8-hour day of crude pyrite should have crushing machinery consisting of a

FLOW SHEET

50-TON COAL PYRITE CONCENTRATING PLANT

FOR

BON AIR—CLIFTY DISTRICT



common Blake or gyratory rock crusher, followed by a pair of smooth rolls. This should be followed by a 3-compartment plunger jig having compartments about 2 feet square. Following this jig should be a pair of small rolls for recrushing the partly cleaned middling products from the jigs, and following these rolls should be a concentrating table for saving pyrite from the crushed material.

The necessary power, building, water supply and bins should probably bring the total cost of a pyrite concentrating plant up to about $14,000 at the present time. For a 100-ton plant per 8-hour day the total cost would be about $20,000.

Publications of Geological Survey of Tennessee Issued.

The following publications have been issued by the present Survey, and will be sent on request *when accompanied by the necessary postage.*

BULLETIN No. 1—Geological Work in Tennessee.

A. The establishment, purpose, object and methods of the State Geological Survey; by Geo. H. Ashley, 33 pages, issued July, 1910, postage, 2 cents.

B. Bibliography of Tennessee Geology and Related Subjects; by Elizabeth Cockrill, 119 pages; postage, 3 cents.

BULLETIN No. 2—Preliminary Papers on the Mineral Resources of Tennessee, by Geo. H. Ashley and others.

A. Outline Introduction to the Mineral Resources of Tennessee, by Geo. H. Ashley, issued September 10, 1910; 65 pages; postage, 2 cents.

D. The Marbles of East Tennessee, by C. H. Gordon; issued May, 1911; 33 pages; postage, 2 cents.

E. Oil Development in Tennessee, by M. J. Munn; issued January, 1911; 46 pages; postage, 2 cents.

G. The Zinc Deposits of Tennessee, by S. W. Osgood; issued October, 1910; 16 pages; postage, 1 cent.

BULLETIN No. 3—Drainage Reclamation in Tennessee; 74 pages; issued July, 1910; postage, 3 cents.

A. Drainage Problems in Tennessee, by Geo. H. Ashley; pages 1-15; postage, 1 cent.

B. Drainage of Rivers in Gibson County, Tennessee, by A. E. Morgan and S. H. McCrory; pages 17-43; postage, 1 cent.

C. The Drainage Law of Tennessee; pages 45-74; postage, 1 cent.

BULLETIN No. 4—Administrative Report of the State Geologist, 1910; issued March, 1911; postage, 2 cents.

BULLETIN No. 5—Clays of West Tennessee, by Wilbur A. Nelson; issued April, 1911; postage, 4 cents.

BULLETIN No. 9—Economic Geology of the Dayton-Pikeville Region, by W. C. Phalen; issued May, 1911; postage, 4 cents.

BULLETIN No. 10—Studies of the Forests of Tennessee.

A. An Investigation of the Forest Conditions in Tennessee, by R. Clifford Hall; issued April, 1911; 56 pages; postage 3 cents.

B. Chestnut in Tennessee, by W. W. Ashe, issued December, 1911; postage, 2 cents.

C. Yellow Poplar in Tennessee, by W. W. Ashe, issued January, 1914; 55 pages; postage, 3 cents.

BULLETIN No. 13—A Brief Summary of the Resources of Tennessee, by Geo. H. Ashley; issued May, 1911; 40 pages; postage, 2 cents.

BULLETIN No. 14—The Zinc Deposits of Notheastern Tennessee, by A. H. Purdue; issued September, 1912; 69 pages; 30 illustrations; postage, 3 cents a number.

BULLETIN No. 15—Administrative Report of State Geologist, 1912.

BULLETIN No. 16—The Red Iron Ores of East Tennessee, E. F. Burchard; issued November, 1913; 172 pages; postage, 8 cents.

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Characteristic Properties of Ball and Plastic Refractory Bond Clays ..... By Cullen W. Parmelee

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Ball Clays of West Tennessee

By Rolf A. Schroeder

With laboratory tests made at the Ceramic Laboratories, University of Illinois, and notes by Cullen W. Parmelee.

Introduction.

This report deals primarily with ball clays, which are in great demand at the present time, but occur very sparingly in our country, the majority of deposits being in West Tennessee and just across the line in Kentucky. Such high grade clays are used in the manufacture of porcelain, glass-pots, crucibles, enamel ware, etc. Many firms complain that the supply does not meet the demand and that they have to import from Europe. Moreover, ball clay is a "war mineral," and consequently its exploitation and development are matters of importance. Most of the clay mined here is shipped to other states, where it is manufactured into high-grade porcelain, electric and enamel ware, crucibles, etc. It would be a great boon to Tennessee if a ceramic industry were established here where the clay is found. This report and the accompanying tests will give an impetus, it is hoped, to prospecting and development of clay manufacturing in the South.

[1]"The principal recent concern of the American manufacturers has been to find a substitute for the high grade clays formerly imported from Germany and used in the manufacture of glasshouse supplies, crucibles, lead pencils, emery wheels, etc. At the beginning of the war the users of these clays were apparently well supplied with them. As stocks became depleted, with no prospect for a resumption of imports, the manufacturers of high grade refractory products turned to the United States Geological Survey for information as to sources of domestic clays suitable for these uses."

Bleininger and Schurecht[2] of the Bureau of Standards, have shown the feasibility of substituting domestic for foreign clays and com-

[1]From U. S. Geol. Survey Bull. 666-T, by Jefferson Middleton, 1917.

[2]Bleininger, A. V, and Schurecht, H. G. Properties of some European plastic fire clays: Bur. Stand. Tech. Paper 79, 1916.

ment as follows on the situation: "The question of replacing the plastic clays imported from Europe in considerable quantities up to the outbreak of the European war has been of importance to the industries concerned. The materials which are chiefly concerned are the Gross Almerode clay for the glass, and the Klingerberg clay for the graphite-crucible and allied industries. Some of the users of these clays have sought to replace them by individual American clays. There is no reason to believe that such clays cannot be found in the United States; in fact, materials have been tested in this laboratory which approach the foreign clays in quality. It would be far better, however, to depend upon a mixture of two or more clays, representing both clays of the open and more refractory and of the dense and vitrifying variety, to secure the desired condition. Since such clays as those from the St. Louis, Mo., district have been used for years

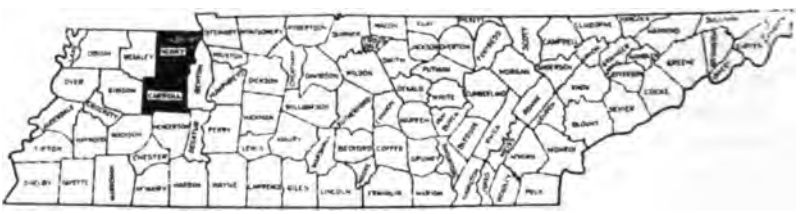

FIGURE 1—Key map of Tennessee showing location of Henry and Carroll Counties.

with good success in glass-pot mixtures, in conjunction with the European clays, it would not be difficult to supplement their qualities by means of materials vitrifying at lower temperatures and not subject to overburning within a considerable range of temperature. Such clays, it is true, are not common, but may be found among the ball clays, or semi-ball clays, of Tennessee and Kentucky * * *."

The field studies which form the basis of this report were made by the writer during the summer and fall of 1918 under the direction of the State Geologist, and in co-operation with the United States Geological Survey.

The writer wishes to acknowledge the valuable advice of Wilbur A. Nelson, State Geologist, and the assistance rendered by operators, owners and numerous persons interested in the deposits concerned.

The area surveyed comprises about 3,500 square miles, including most of that part of the State west of the Tennessee River. (See Fig. 1.)

The object of the investigation was to obtain full information concerning the location, geological relations and economic importance of the ball clays of West Tennessee and to obtain thorough tests on these clays by an expert ceramist.

Among those who have made previous investigations in this region are J. M. Safford,[1] L. C. Glenn,[2] Wilbur A. Nelson,[3] Bruce Wade,[4] Stephenson[5] and Berry.[6]

The Method Pursued in Field Investigation.—The most important towns of the region were visited for a period ranging from one day to several weeks, depending upon their proximity to important clay deposits. Posters, advertising the object of the work and requesting clay property owners to communicate with the field geologist, were placed in conspicuous places, and the work was otherwise made known to the public by means of newspaper accounts and personal interviews with leading men of the various towns. Where the clay deposit looked promising a geological examination was made and a fair sample of clay collected and forwarded to Cullen W. Parmelee, Professor of Ceramic Engineering at the University of Illinois, where preliminary, and in some cases complete, tests were made, the results of which are incorporated in this report under the local descriptions of pits and prospects. The methods of making these tests are discussed in a separate chapter by Mr. Parmelee. In some places auger holes were bored to determine the thickness of the clay stratum or to procure a fresh sample.

Field Method for Distinguishing Ball Clays.—Ball clays should possess a high degree of plasticity, that is, they should cohere like putty. A good test is to whittle off some thin shavings from a fresh sample with a pocket knife. It is quite impossible to obtain long, thin pieces which will not break or crumble unless

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[1]Safford, J. M., Geology of Tennessee. Nashville, 1869.

[2]Glenn, L. C., Underground waters of Tennesse and Kentucky, etc., U. S. Geol. Survey Water-Supply Paper 164.

[3]Nelson, Wilbur A., The clays of West Tennessee. Tenn. Geol. Survey Bull. 5.

[4]Wade, Bruce, Geologic map of McNairy County (in preparation).

[5]Stephenson, Lloyd William. Cretaceous deposits of the eastern Gulf region and species of exogyra from the eastern Gulf region and the Carolinas. U. S. Geo. Survey Prof. Paper 81.

[6]Berry, Edward W. The lower Eocene floras of southeastern North America. U. S. Geol. Survey Prof. Paper 91.

the specimen is ball clay. In boring through ball clay with an auger, the borings should come up in long coils, which do not break, and retain the shape given them by the convolusions of the instrument. A peculiar snapping sound, like the discharge of an electric spark, is commonly heard while boring through fat ball clays and the instrument is pulled down into the clay rapidly, no pressure being necessary, but in gritty, non-plastic clays it is sometimes impossible to bore faster than a foot an hour, employing the utmost downward pressure. Ball clays can be bored several feet in as many minutes. They should have a greasy feel like soap. No sand, mica or grit of any sort should be present. Usually these impurities can be felt with the finger, but a good test is to place a small particle between the teeth and the finest grit will be easily perceptible.

Red, rusty, bright yellow, or black clays will not burn white and hence are not ball clays. White, pale pink, grey, bluish, or brown colors may burn out and these colors may be present in ball clays.

Lastly, ball clay should be homogeneous, having no parting planes such as bedding or close jointing.

Summary.

The economically important clays of West Tennessee occur, with few exceptions, in Henry and Carroll counties. The geologic horizons in which the clay lenses are found are the upper portions of the Ripley (Upper Cretaceous), and the lower Lagrange (Eocene), both consisting of unconsolidated quartz sands. Although clay strata are abundant south of these counties they are for the most part less "pure" and not suitable for ball clay. The common adulterants are quartz, mica and iron compounds. The best ball clays of Henry and Carroll counties seem to be associated with lignite. Very high grade clays are found in these counties, ranking favorably with imported European clays. In all, fifty-nine samples were collected and given preliminary tests. Nineteen were given complete tests. Thirty-four samples represent unworked deposits, of which about 90 per cent are of economic value and the deposits from which they were taken should be developed.

At the present time four or five concerns are mining most of the high grade clay produced in the State. Many good deposits are idle, due to lack of prospecting and initiative on the part of the owners. Another obstacle to further development of new deposits is the reti-

cence on the part of consumers, especially potters, to use a clay they are unaccustomed to, preferring the clay they know to one that may be better and lower priced. Without full tests, often expensive, the prospective producer cannot tell for which purpose his particular clay is best suited and consequently does not cater to the proper industry.

Geographic Distribution.

In Tennessee ball clays are abundant in Henry County, occur to a lesser degree in Carroll County, and sparingly in Haywood and madison counties. In Kentucky[1] they are found in Ballard, Calloway and Hickman counties, mostly in the northern extension of the same formations in which the Tennessee ball clays occur. They are also mined at Edgar, Fla., Woodbridge, N. J., and in Missouri. Foreign localities are England, Austria and Germany.

Topography.

The surface of Tennessee west of the Tennessee River, varies from a very flat flood plain, along the main rivers and tributaries, to a gently rolling or hilly surface in the interstream areas. Generally the surface is moderately hilly and is cut into bolder hills near the valleys of the larger streams. Several different types of topography are characteristic features of the ball clay areas.

Hills of Erosion.—These constitute an unusually hilly belt in the eastern part of the Lagrange exposure. Here gullies and ravines erode the loose sands rapidly, forming a very rough country.

Flatwoods.—The surface underlain by the Porter's Creek clay, especially near the Kentucky line, is of more than average flatness, which is due to the resistance offered by these clays to erosion and to their nearly horizontal attitude.

Geology.

GENERAL STATEMENT.

The rocks in the region under consideration comprise sands, clays and gravels that range in age from Cretaceous to Recent, though the record is not one of continuous deposition. The sands are generally unconsolidated, though locally thin bands of ferruginous sandstone and conglomerate have been formed by cementation. These, however, nowhere exceed several feet in thickness.

[1]Gardner, James H., Some Kentucky clays, Kentucky Geol. Survey Bull. 6.

GEOLOGIC FORMATIONS.

The oldest rocks represented are Paleozoic limestones, exposed just east of the area surveyed, which form the floor of deposition for all subsequent deposits. The Eutaw Sands and the Selma Clay (Lower Cretaceous) rest unconformably upon this floor. These sands also crop out just east of the area under discussion. Over these lie the Ripley and the McNairy Sand Member of the Ripley (of the Cretaceous); the Porters Creek and the Lagrange of the Eocene; the Lafayette of the Pliocene (considered by Berry[1] to be Pleistocene); and the Columbia of the Pliestocene (considered by Berry[1] to be Recent).

FIGURE 3—Cross-bedding in the Ripley sands north of Buena Vista.

STRATIGRAPHY.

Cretaceous System.

Selma Clay.—The Selma clay is exposed in a narrow belt in the southeast part of McNairy County. It is leaden grey or greenish when dry but blue or black when wet. Fossils are abundant and in certain parts the clay is glauconitic. *Exogyra* (a form related to the oyster) and *Ostrea* (an oyster) are characteristic, while reptile bones are

[1]Berry, Edward W., The lower Eocene floras of southeastern North America, U. S. Geol. Survey, Prof. Paper 91.

occasionally found. The formation is about 100 feet thick at Lexington, but thickens southward.

Ripley and the McNairy Sand Member.—These beds are exposed in a band six to fifteen miles wide which extends north and south entirely across the State through Selmer, Lexington and Hollow Rock. This formation is composed of red, brown, yellow, pink and purple sands, cross-bedded (see Fig. 3) and inter-stratified with clay and lignitic material. Concretionary ironstone is abundant. In places the sand includes clay lenses and some of these are being worked in Henry and Carroll counties. This deposit is very similar in appearance to the Lagrange, and considerable difficulty is encountered in discriminating between the two. The following criteria, however, are at times useful: as a rule the Ripley sands are somewhat more orange in color and more micaceous than those of the Lagrange. The thickness of this formation is about 500 feet. It is very liable to erosion and makes exceedingly rough country. Roads built in these sands are often transformed into gullies unless well cared for.

Eocene Series.

The Porters Creek Formation.—This formation rests unconformably upon the McNairy Sand Member of the Cretaceous and outcrops immediately west of the latter in a band averaging four miles in width and traversing the State from north to south.

It is composed mainly of dark, fine-grained, micaceous, sandy clay, which is pale grey when dry but black when wet, and is locally known as "soapstone." On weathered surfaces it possesses a peculiar concentric fracture, giving it a ball-like appearance. Locally, it is penetrated by thin, sandstone dikes. The lower part of this formation also contains interbedded, fine, micaceous, silty sands and greensand. The latter may contain enough calcareous matter to cement certain layers into impure limestone.

The thickness of this formation averages 175 feet. It's surface exposure is unusually flat and the country underlain by it is generally termed "the Flatwoods."

Lagrange Formation.—This formation is of Wilcox age and outcrops immediately west of the foregoing one in a band of variable width. It underlies all of the area under consideration in this report west of the Porters Creek exposure. A thin capping of Lafayette and Columbia loess and loam conceals it in the western portions.

It is composed of cross-bedded and interbedded sands, clays, lignitic matter and thin gravel beds. Clay conglomerates (see Fig. 4) and breccia occur locally. Much the larger part is sand, which is mostly fine-grained, and is composed of semi-rounded particles of transparent, colorless quartz, chert and muscovite flakes. The color of the sand is usually a cream or light orange, though brown, red, pink and purple is common. A thin veneering of iron compounds upon the sand grains generally causes the coloration.

The clays of this formation are the best in West Tennessee, grading from the best ball clays down to common brick clay. The clay lenses occur in its upper horizons and are generally associated with

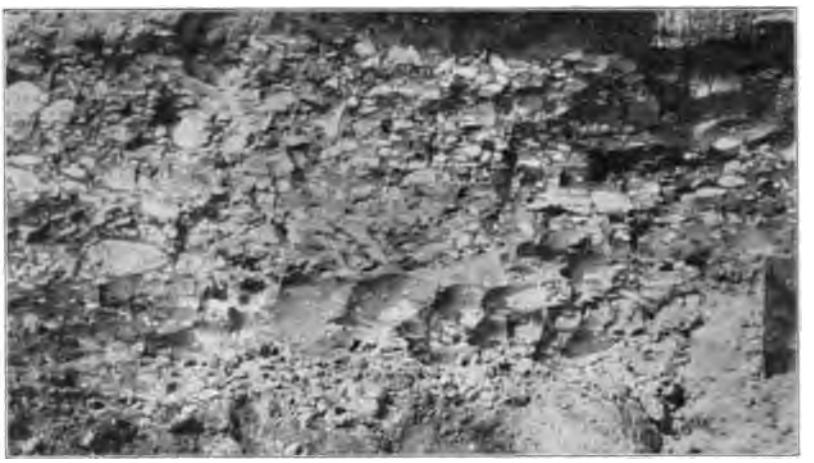

FIGURE 4—Clay conglomerate near Pinson. Scale, 1 inch=10 inches.

lignitic beds. These lenses as a rule cover several acres and are elliptical in plan, their long axes trending several degrees west of north, in Henry and Carroll counties, while in the southern counties they extend east of north. In short there is a tendency towards an alignment parallel to the ancient shore line.

The thickness of this formation varies from 148 feet at Jackson to 936 feet at Memphis.

Pliocene Series.

Lafayette Formation.—Over all the formations just described and extending eastward over the adjoining Paleozoic rocks, there is a thin blanket of brick red sand, clay and gravel, having an average thick-

ness of twenty feet. The sands are characteristically case-hardened and massive, and frequently stand up in vertical walls or "knife-edges" where subjected to erosion. The sands are often accompanied by gravel, which usually forms the basal part. They are especially prominent in the region about Puryear in Henry County, and are composed of novaculite, quartzite and chert. These gravels are considered by Wade[1] to be stream terrace deposits, laid down by the Tennessee River, the detritus being derived from its headwaters in northern Alabama.

Pleistocene Series.

*Columbia Formation.**—This is a thin blanket of loose, brown sand, loess and loam which rests upon the Lafayette sands in this region. It varies in thickness from zero to five feet.

STRUCTURAL GEOLOGY.

These sands and clays lie in the eastern half of an embayment of the ancient seas, which projected northward from the Gulf region and ended in southern Illinois. They were laid down on the floor of this embayment in broad, successive superimposed sheets. At the northern end of this trough in Illinois, the formations rise to the surface like the tip of a spoon. The western half lies in southwestern Missouri and eastern Arkansas. The eastern part crops in parallel zones, trending north and south across the State, the strata dipping gently (thirty feet per mile) towards the west. They have not been subjected to any extensive folding or faulting, the folds being limited to minor crenulations and slight warpings, which have in some cases given rise to symmetrical, dome-shaped hills of low elevation (see Fig. 2). The New Madrid earthquake, which formed Reelfoot Lake,[2] was accompanied by faulting. At this time small sandstone dikes[3] were intruded in the Porters Creek clay.

HISTORICAL GEOLOGY.

The oldest and deepest rocks in this region are the Paleozoic limestones, whose eroded surface formed the sea floor upon which were

*Considered to be Pleistocene by Berry.

[1]Gravels of West Tenn. Bruce Wade, *The Resources of Tenn.*, Vol. VII, No. 2, p. 67.

[2]Fuller, Myron F., The New Madrid earthquake. U. S. Geol. Survey Bull. 494.

[3]Fossiliferous sandstone dikes in the Eocene of Tennessee and Kentucky: abstract from Science, new Ser. Vol. 19, 1904, p. 522.

deposited the Cretaceous and Eocene rocks already described. Towards the end of the Upper Cretaceous the waters were shallow and brackish as indicated by well developed cross-bedding, the presence of leaves and other organic matter in the clay. This period was followed by uplift and subsequent depression, allowing the deposition of the Porters Creek clays in deeper water. The region was again elevated and the Lagrange sands and clays were deposited in brackish, shallow water. (See "Origin of Clay Lenses," p. 92.) During the Oligocene and Miocene the region was lifted out of the sea and remained land until it again subsided in Pliocene time enabling the deposition of the Lafayette sands and the Columbia loam. Then followed another elevation and consequent withdrawal of the seas, exposing the land to erosion, bringing about the major features of the

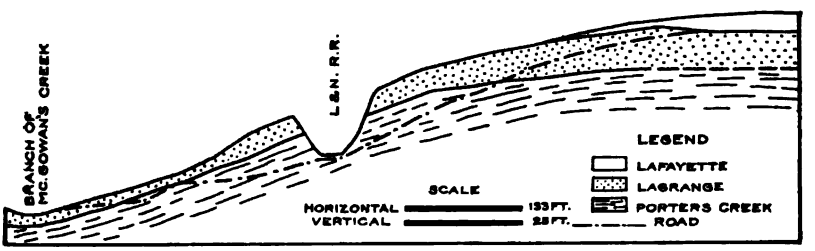

FIGURE 2—Geologic profile section on road to Puryear, on hillside in outskirts of Paris.

present topography. A slight uplift has occurred in recent times, causing the creeks to incise their valleys in their old flood planes to a depth of from two to twenty feet. The old plane is known as the "second bottoms." Minor faulting and warpings have also occurred in recent times.

ECONOMIC GEOLOGY.

Clay, sand and gravel are the only substances of any economic importance contained in these rocks.[1]

The McNairy Sand Member of the Ripley and the Lagrange formations contain ball, sagger and pottery clays; and the Lafayette

[1]The possible occurrence of oil and gas in West Tennessee has recently been arousing some interest. Although none has been found up to the present time, the possibility exists of finding an oil sand here. It is a difficult matter to work out the structure because the contacts are for the most part concealed by the overlying Lafayette sands.

sands are argillaceous enough in places to afford good brick clay.

Sand is mined, especially in the region around Grand Junction, and is used to make plate glass and concrete.

Uses of Ball Clay.

Ball clays are extensively used as a necessary ingredient of white ware mixtures in order to give the body sufficient plasticity and bonding power. The following list enumerates some of the more important ues of ball clay:

1. *Electric Porcelain Ware and Insulators.*—Ball clay, china clay, feldspar and quartz are used in the manufacture of these articles. The function of the ball clay is to increase the plasticity of the mixture so that the many intricate designs which are required can be readily pressed or formed.

2. *Porcelain or China.*—This is made of ball clay, kaolinite, quartz and calcium phosphate or feldspar, depending upon whether a soft or hard ware is desired.

3. *Plate Glass Industry.*—Ball clay is used in making pots in which optical glass is melted. These pots are used but once and are made out of high grade kaolinite with 20 to 30 per cent of ball clay to bind the kaolinite. It also has the effect of increasing the density of the pot when burned.

4. *Sanitary Ware and Enamel Ware.*—This ware is made at extremely high temperature. Hence, a very refractory clay is desirable. The white ball clay from the Dalton Mine, near McKenzie, is used for this purpose.

5. Ball clay is also used in making graphite crucibles, as a binder in abrasive wheels, in the pottery industry, in making greenhouse ware, tiling, lead pencils, chemical ware and cosmetics.

Production and Prices.

In Tennessee, according to reports from operators, the total output of high grade clay for the last fiscal year approximated 65,000 tons. Production was somewhat impeded by freight embargoes and scarcity of labor. The leading producers are the Mandle Clay Mining Co., of St. Louis; Johnson-Porter Clay Co., of Paris, Tenn.; H. C. Spinks Clay Co., of Newport, Ky.; Cooley Ball and Sagger Clay Co., of Hazel, Ky., and A. Nunnelly, Hollow Rock, Tenn.

The average price commanded by sagger clay is $3.00 per ton f.o.b. mines, and of ball clay about $6.00, although the price is

governed somewhat by market conditions, some clays varying considerably from these figures. [1]"While the importation of the Gross-Almerode, Vallendar, and other German clays was entirely cut off during the war, that of English clays was not seriously interfered with. The agitation in this country over the possible curtailment of imports brought the English clay miners to the realization, heretofore not evident, of the extent of our dependence upon their clay, with the result that within about a year their price has risen nearly 100 per cent. This development has aroused consumers to redouble their efforts to find suitable domestic substitutes. That their search has been at least partly successful is shown by the fact that clay imports have been steadily decreasing and that at the present rate the 1919 total will be only about 50 per cent of that of a normal pre-war year." War conditions have caused considerable fluctuations in the price of ball clay, but no doubt when normal conditions return the equilibrium of the clay market will be restored. Normally a haul of more than six miles to the nearest railway is prohibitive even if the clay is high grade.

Origin of the West Tennessee Clay Lenses.*

Clays are invariably of secondary origin, and are the result of decomposition of pre-existing rocks or minerals. They may remain in place as residual clays or may suffer transportation and redeposition as sedimentary clays. This latter is the type we are dealing with in West Tennessee. Nevertheless, a few words regarding the formation of the primary clay may be in place. Residuary clays (kaolinite, halloysite and allied species) are largely derived from the decomposition of feldspar or feldspathic rocks. This may be effected by pure water (hydrolysis) with the development of colloidal gels, but is hastened by the action of carbon dioxide and sulphuric acid. Rain water and carbon dioxide from the air react upon feldspar and change it to kaolinite. Sericite and other minerals are also known to yield kaolinite.

The kaolinite (or allied species) thus formed remains as a residual mantel over the parent rock until attacked by erosion, when it be-

[1]Excerpt from monthly report on mineral investigations by the Bureau of Mines, Department of the Interior, March, 1919.

*The writer has made no attempt to make an exhaustive study of this subject. There was no time available for careful investigation, and, moreover, the purpose of this paper is primarily economic and hence it is treated only in a general way.

comes liable to transportation. The assorting and transporting power of running waters rarely allows such residual clays to remain in the place of their origin. The minute size and shape of the constituent particles are such as to render them easily transported by rains and running streams, to be redeposited in stratified beds when the carrying power is lost by the checking of the current, when they flow into lakes and seas. Thus it is evident that clay particles are originally derived from igneous rocks.

The nearest igneous rocks to the embayment deposits will be found in the Appalachian region.

In a discussion of the origin of West Tennessee clays, the following considerations are significant:

1. The Ripley and Lagrange formations in West Tennessee are composed essentially of transparent colorless grains of quartz, muscovite mica and clay (in places micaceous)—the three important decomposition products of a granite.

2. The general configuration of the Cretaceous and Eocene shore line would suggest a source of supply situated in central Tennessee and Kentucky, northeastern Alabama and northern Georgia.

It will be seen that this is the locus of existing or pre-existing argillaceous shales, sandstones and conglomerates of Carboniferous age whose original home was in the granite rocks of the Appalachians

Glenn[1] attributes the primary origin of the clay substance embodied in these deposits to the disintegration of chert and the weathering of limestone in nearby Paleozoic rocks, but he does not account for the presence of white mica in the clay and overburden. Watkins[2] says: "Though this area seems far removed from the crystalline area of the southern Appalachian region, it should be remembered that the waters of Tennessee River, which must have once deposited their burden along this coast line, have their origin far into the crystalline area. Besides this, beds of white clay similar to the West Tennessee clays occur almost continuously in the Cretaceous from Tennessee through Mississippi and Alabama to Georgia. It would seem that a part of the clay may have had its origin in the residual clays of the crystalline rocks."

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[1]Glenn, L. C., Underground waters of Tenn. and Ky. west of Tenn. River, W. S., 164, p 34.

[2]Watkins, Joel H., White-burning clays of the Southern Appalachian States: Am. Inst. Min. Eng., Bull. No. 98, p. 407.

The following theory seems tenable:

(1) That these sands are in part derived from the erosion and redeposition of Carboniferous strata, and in part represent original residual matter from granitic rocks to the east.

(2) That the clay, once incorporated in these rocks has been transported, resorted and redeposited in brackish or fresh water, very near shore or in lagoons, under conditions of comparative tranquility.

(3) That the ball clays in particular, which are confined to northern portions of West Tennessee and southern Kentucky, were deposited at a time of subsidence of the old land surface, the streams being excessively sluggish and of low gradient, with correspondingly decreased transporting power. The clay was probably deposited in lagoons close to shore or in the irregularities of a low, flat land surface, such as ponds or swampy depressions. The presence of numerous leaf impressions in a perfect state of preservation, fossil wood and nuts, corroborates this idea.

The following is an excerpt from Berry's[1] description of a section about one-fourth of a mile south of the depot at Puryear, immediately west of the N., C. & St. L. Railway, in a clay pit (Mandle Clay Mining Co., now abandoned):

"This is the most remarkable leaf-bearing clay that I have ever seen at any geologic horizon. The fossiliferous layers are practically without sand and must have been deposited in very quiet waters. They are crowded with leaves that lie horizontally, but not in matted layers. There is no evidence of seasonal accumulations. * * * The plants must have grown near at hand, for they could not have withstood much transportation. Indeed, most of the forms are evidently coastal types."

"I picture the Wilcox conditions here as an area at the mouth of a Wilcox stream of low gradient, carrying only the finest sediments, that emptied into a lagoon lined on the landward side by a sand beach supporting a typical subtropical strand vegetation and separated by a considerable barrier beach from the main body of embayment waters. That it was not an estuary or bayou seems to be indicated by the lack of carbonaceous muds and the presence of a few gypsum crystals."

[1]Berry, Edward W., The lower Eocene floras of southeastern North America, U. S. Geol. Survey, Prof. Paper 91, p. 48.

The local occurrence of chert, quartzite and novaculite gravels does not disprove the theory just presented. Cherts are common in the Paleozoic rocks not only as concretions but as well-rounded gravel, and we would naturally expect to see their waterworn remains in the younger strata. They form a very small percentage of the total detritus.

Wade[1] has the following to say regarding the origin of these quartzite pebbles: "There are no quartizite or quartz country rocks in the vicinity of West Tennessee, so these gravels were probably derived from the conglomerate horizons in the Pennsylvania series occurring in northern Alabama and East Tennessee. * * * The similarity between these terrace pebbles and the Lee conglomerate of the Cumberland Mountains is striking."

Origin of the Ironstone Concretions.

When waters, saturated with iron compounds, descend through unconsolidated sands, they are liable to encounter obstructions on

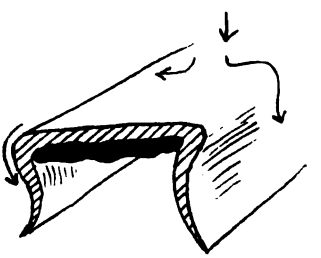

Figure 5—Sketch to illustrate origin of ironstone concretions. Arrows indicate direction taken by descending waters. Black portions represent a clay pellet and cross-hatched portions represent the concretion in section.

their downward path and precipitate iron oxide or hydroxide upon these. The obstruction is usually a clay pellet but may be a fossil or merely a coarse stratum of sand. The depositing solutions follow this horizontally and trickle down over the edges, forming, in some cases, stalactitic, curtain-like appendages. (See Fig. 5.) This accounts for the frequent occurrence of iron hard-pan beds immediately above clay deposits, and also for the very white and pure quartz sands immediately below. Saturated chalybeate solutions will precipitate upon the

[1]Wade, Bruce, Gravels of West Tennessee, Resources of Tenn., Vol. VII, No. 2.

slightest particles which may impede their downward progress, such as rootlets, fossils, unusually coarse grains or zones of sand, small clay pellets, etc. A concretion found by the writer at Pit No. 9 of the Cooley Ball and Sagger Clay Co., had the shape of a perfect spherical shell, which enclosed a little loose sand and a yellow clay pellet.

Definitions of Clays.

Clay is a term applied to those earthy materials occurring in nature whose prominent property is that of plasticity when wet and induration when dry. Clays are composed of many different minerals in a fine state of division, of which kaolinite is the most characteristic. Following is a list of minerals found in West Tennessee clays by means of the polarizing microscope:

*Minerals in Tennessee Clays.**

Clays from the Ripley Formation.	Quartz	Hydromica	Kaolinite	Rutile	Zircon	Tourmaline	Epidote	Titanite
Sagger clay, Hollow Rock	C	A	C	C		S		
Sagger clay, Hollow Rock	C	A	A	A	S			
Lignitic clay, India	S	A	C	S				
Brown sandy clay, Currier Pit, Paris	C	A	A	A		S		S
Dark clay, Currier Pit, Paris	C	A	C	S				
Clays from the Lagrange Formation.								
Clay lens in Dale's Sand Pit, Lagrange	A	S	A	M	S	S		S
McNanee Pit, Lagrange	C	A	A	A	S			
No. 10 Ball clay, Johnson-Porter Clay Co., McKenzie	S	A	A	S		S		
No. 11 Ball clay, Johnson-Porter Clay Co., McKenzie	S	A	A	S				
Sparks Pit, McKenzie	S	A	A	M		S	S	
Sagger clay, Chrisman-Reynolds Pit, Henry	A	A	C	C	S	S		
No. 1 S. G. P., Mandle Clay Mining Co., Whitlock	S	A	C	C		S		
No. 5 Ball clay, Mandle Clay Mining Co., Whitlock	S	A	C	S				
No. 7 Ball clay, Mandle Clay Mining Co., Whitlock	S	A	C	S		S		
No. 4 Ball, white, Mandle Clay Mining Co., Whitlock	S	A	C	A		S		

*The petrographic data given in this table were obtained from Dr. R. E. Somers of the U. S. Geol. Survey.

	Quartz	Hydromica	Kaolinite	Rutile	Zircon	Tourmaline	Epidote	Titanite
No. 4 Ball, dark, Mandle Clay Mining Co., Whitlock	S	A	C	S				
Wad clay, Cooley Ball & Sagger Clay Co., near Hazel, Ky.	C	C	A	C		S		
Dark Ball clay, Cooley Ball & Sagger Clay Co., near Hazel, Ky.	S	A	C	A	S			
Dixie Brick & Tile Co., Puryear	C	C	VA	S	S	S		S

Note. A—Abundant M—Moderate amounts
VA—Very abundant S—Scarce
C—Common

The foregoing table shows us that in these clays quartz is always present in variable amounts, that mica is, as a rule, abundant, and kaolinite is common to abundant. The presence of quartz and mica is a suggestive fact in a consideration of the genesis of these clay beds. Moreover it will be seen that rutile is common and that zircon, tourmaline, epidote and titanite also occur, which immediately suggests an igneous rock origin for these clays. Doubtless they were derived, in part at least, directly from the granitics of the Appalachian region.

Another important constituent of clay is colloid gel, concerning which Ashley[1] says: "It forms an enveloping coating upon most of the mineral grains, and consists of non-crystalline, hydrated gelatinous aluminum silicates, organic colloids, gelatinous silicic acid and hydrated ferric oxide. Quartz and mica grains which are usually present, do not have the colloid coating, or have it in a much less degree. If this granular matter is in excess the clay is called sandy, weak or *non-plastic*, but if the colloid matter is in excess the clay is considered *very plastic*, fat or sticky."

It will be seen from the foregoing that clay is an aggregate of minerals and consequently is not a mineral but a rock. Chemically, clay consists of hydrous and anhydrous aluminum silicates, free silica and varying amounts of iron and other oxides, carbonates, silicates, etc., in short of stable compounds generally having low specific gravities.

[1]Ashley, H. E., The colloid matter of clay and its measurement, U. S. Geol. Survey Bull. 388, p. 8.

Ball clays are highly plastic, refractory, white or nearly white-burning clays of sedimentary origin, possessing high tensile strength and homogeneity. Consequently they should contain no iron compounds, free silica, mica or grit and should possess no tendency to part along bedding planes. Probably so-called from their striking property of "balling up" or cohering.

Sagger clays are tough, plastic, refractory clays having low shrinkage and are commonly rather siliceous and may be well stratified; in short they are impure ball clays. They are so called from their use in making receptacles known as "saggers," in which the better grades of ware are enclosed during burning.

Wad Clays are low grade, siliceous clays, not necessarily tough or plastic, which are used for grouting or filling up the joints between the saggers, when they are piled one upon another in the kilns.

Properties of Clay.

*Plasticity**—Plasticity[1] is the property which many bodies possess of changing form under pressure, without rupturing, which form they retain when the pressure is removed.

The causes for plasticity are discussed under the definition for clay on page 95. Plasticity is closely related to the amount and kind of colloid matter present and the degree of comminution of the mineral particles. The most highly plastic clays are those that have been subjected to the action of water for long periods. The longer the mineral particles remain in suspension in water the more liable they become to corrasion resulting in still finer division and the more complete is the sorting action. Davis[2] says the following regarding suspension:

"Clay particles suspended in water take on negative electric charges and continually repel one another. Consequently this tends to keep them in suspension. The presence of organic and emulsion colloids greatly increases the stability of suspension and are known as protective colloids. To test the effect of organic matter on suspension,

*As plasticity is the most prominent property of ball clay, it is discussed rather fully in this report. This subject is also taken up in the accompanying paper by Cullen W. Parmelee.

[1]Ries, H., Clays, occurrence, properties and uses, 2nd ed., 1908, p. 119.

[2]Davis, N. B., The plasticity of clay and its relation to mode of origin: Am. Inst. Min. Eng., Bull. No. 98, pp. 301-330.

a couple of pounds of Delaware washed kaolin, water, and an ounce of peat were placed in a ball mill. After ten hours' mixing the slip was drawn and allowed to dry. It was then mixed with water to a plastic mass. Comparing the resultant plasticity with that in a portion of untreated kaolin, it was found to have increased. Samples of the treated and untreated material were then suspended in water and allowed to settle. After ten hours it was observed that the untreated kaolin had settler clear, while the treated portion showed considerable matter in suspension."

That plasticity is closely related to organic content is evidenced by the common occurrence of lignite in the best clay beds of West Tennessee.

Ashley[1] says that it has been the custom for many years to add various gelatinous substances to clay to improve its working qualities. Some of these are gelatin, glue, starch, gum arabic, dextrine, milk, sodium silicate, cow and horse dung and rotten paper. Acheson,[2] Auclair[3] and Keppler[4] have patented certain methods for improving plasticity by means of colloidal chemical processes.

Ashley[1] has shown that it is possible to measure plasticity by observing the power a given clay has for adsorbing malachite green dye. He has made interesting and extensive tests on many clays, among which are certain important Tennessee clays. The results are shown in the following table. The figures are very instructive, for they give us a numerical conception of relative plasticities.

Plasticity of Tennessee Clays.

Mandle Clay Mining Company, "Special Sagger"	9.09	?
Mandle Clay Mining Company, "Tenn. Ball No. 3"	5.96	
Johnson-Porter Clay Company, "Tenn. Ball No. 9"	5.76	
Potter's Supply Company, "Tenn. No. 3"	4.62	
Potter's Supply Company, "Tenn. No. 4"	4.52	
Johnson-Porter Clay Company, "Tenn. No. 10"	3.45	
Johnson-Porter Clay Company, "X Wad"	1.867	?
Johnson-Porter Clay Company, "UX Wad"	1.824	

(*Table continued on following page.*)

[1]Ashley, H. E., The colloid matter of clay and its measurement, U. S. Geol. Survey Bull. 388.

[2]British Patent No. 7776, Apr. 3, 1907.

[3]French Patent No. 372858, Dec. 22, 1906.

[4]German Patent No. 201987, Aug. 4, 1906.

Potter's Supply Company, "Wad"	1.775
Mandle Clay Mining Company, "Wad"	1.530 ?
Mandle Clay Mining Company, "Tenn. No. 9"	1.473
Johnson-Porter Clay Company, "No. 1 Ball"	1.378

Note.—? indicates values probably too high, due to experimental errors.

*Fusion point** is the temperateure at which a substance melts or fuses, and is measured by means of Seger or pyrometric cones. These are test pieces consisting of a series of mixtures of clays and fluxes, so graded that they represent a complete series of fusion points, each but a few degrees higher than the next one to it. Following is a list[1] showing the fusion points of a few of these cones:

Fusion Points of Seger Cones.

Cone No.	F.°	C.°
.022	1,094	590
.07	1,850	1,010
1.	2,102	1,150
2.	2,138	1,170
5.	2,246	1,230
9.	2,390	1,310
10.	2,426	1,330
12.	2,498	1,370
13.	2,534	1,390
20.	2,786	1,530
27.	3,038	1,670
28.	3,074	1,690
29.	3,110	1,710
30.	3,146	1,730
31.	3,182	1,750
32.	3,128	1,770
33.	3,254	1,790
39.	3,470	1,940

*Porosity** is the state of being porous, or having pores. Pores are the spaces existing between the particles which constitute the porous substance. The porosity of clay is measured by the difference in weight of the burned ware before and after being soaked in water. Generally low porosity is desirable in clay ware, as this increases its resistance to weathering.

*For a further discussion of this subject see companion paper by Cullen W. Parmelee.

[1]Ries, H., Clays, occurrence, properties, and uses, 2nd ed., 1908, p. 181.

*Shrinkage** is the contraction which takes place when clays are dried or heated. This reduction in volume is caused by the escape of moisture and other volatile constituents and amounts to twelve per cent in some clays. Therefore, this loss must be allowed for in molding. Shrinkage varies with the temperature.

*Tensile strength** of clay is the resistance which it offers to rupture when air dried. The force required to pull apart certain Tennessee clays varies between 50 and 112 pounds per square inch.

*Vitrification** of clay occurs when its grains become sufficiently softened by heat to coalesce and render the mass impervious. Complete vitrification takes place at the point of maximum shrinkage.

Adsorption is the property possessed by colloids (and necessarily by clays) of taking other substances out of solution or suspension. This property is closely related to plasticity, which latter can be measured by observing the amount of dye (malachite green) that a given clay will take from such a solution. (See *plasticity*.)

*Color** in clay is very variable. The two chief coloring agents are iron compounds and organic matter. Manganese occurs more rarely. A clay free from these is generally white. Carbonaceous matter colors clay blue, grey, brown, black, or even purplish. Three per cent is probably sufficient to produce a pure black. Iron oxide colors clay yellow, brown or red. Greenish color may be due to iron silicate or glauconite. Dry clays are usually lighter in color than wet ones.

When clays are burned their color generally changes. White clays, of course, burn white and red clays burn red, but pale pink clays burn white; deep yellow ones burn buff or red; grey or black ones may burn red, buff, or white; green ones usually burn red; and those whose coloring matter is wholly of an organic nature, not in excessive quantities, burn white.

METHODS USED IN MAKING THE TESTS.[1]

PREPARATION OF THE CLAY.

The clay was carefully inspected and its color, degree of uniformity and the presence or absence of fragments of minerals (not clay) and organic matter noted.

*For a further discussion of this topic see companion paper by Cullen W. Parmelee.

[1]The paragraphs under this heading were written by Cullen W. Parmelee.

A sufficient quantity of the clay was then crushed between rolls or in a laboratory mortar. In this operation, care was taken to avoid grinding the material. The purpose was to reduce the clay to particles of sufficiently small size to permit a thorough mixing of the sample. When this crushing was completed, the clay was passed through a twenty-mesh sieve and then moistened with a sufficient quantity of water to bring it to a suitable consistency, after which it was thoroughly worked by hand until the whole mass was of a uniform consistency and freed from air blebs.

MAKING THE TEST PIECES.

When the quantity of clay was sufficient, which ordinarily was the case, the plastic mass was formed into a roll which was slightly smaller in size than the inside diameter of the barrel of a piston press. This press consists of a barrel about fourteen inches long and three inches diameter. At one end is a metal die with an opening one inch square. Fitting snugly in the barrel is a piston head mounted at the end of a long screw. By turning the handle of the crank attached to the other end of the screw, the piston may be made to move in the barrel, forcing the clay out through the die in the form of a long bar having a cross-section of a square inch. This bar was cut into peices four inches long.

When the quantity of clay was insufficient for the method described, the plastic mass was formed into rolls somewhat larger than the brass mold into which they were tamped by hand. This gave trial pieces of dimensions similar to those previously described.

Each piece was marked for identification and also two marks eight cm. (3⅛ inches) apart were made for shrinkage measurements. These test pieces were carefully transferred to suitable drying pallettes before marking.

DRYING AND LINEAR SHRINKAGE.

The test pieces were allowed to dry at room temperature, then transferred to a steam heated drier where they remained at a temperature of about 100° F. for several hours, and finally the drying was completed at 212° F. After cooling, the loss in length due to shrinkage was determined by measuring the distance between the two marks previously made. The linear shrinkage is expressed in terms of the length of the wet piece.

WATER OF PLASTICITY.

This was determined by weighing the wet test pieces immediately after forming and after the drying operation was completed, the plasticity is expressed in terms of the percentage of the weight of difference in weight representing the loss of water. The water of the wet piece.

FINENESS.

One hundred grams of the crushed sample and 800 c.c. of water were thoroughly agitated by shaking in a suitable apparatus for two hours. The mixture of clay and water was passed through sieves of 20, 40, 60, 80, 120, 150, 200-mesh in the order named.

The residue left in the sieve was washed freely and soft lumps were crushed by gentle pressure of the fingers. The residues were then dried and weighed. The results are calculated in terms of the total weight of dry clay used.

SLAKING.

Test pieces in the form of cubes were made from intimate mixtures of equal parts of dry clay and potter's flint. These cubes were cut from bars formed in brass molds in the manner previously described. The dimensions of the freshly made cubes were one inch on the edge.

The cubes were dried first at room temperature, then at a temperature of 160°-170° F., finally at a temperature of 212° F.

When cooled to room temperature these cubes were supported on wire mesh trays (four meshes to the inch) and completely submerged in water at room temperature. Care was taken to avoid agitating the water during the test.

The time required for the cubes to slake or crumble through the wire mesh support was noted.

TRANSVERSE TEST.

The test pieces were formed as bars in the manner already described. They were six inches long and had a cross-section in the plastic state of one square inch. They were first dried at the room temperature, then at a temperature of 140°-150° F. for twenty-four hours and finally at 212°-220° F. for twenty-four hours.

After removal from the oven and cooling to room temperature these bars were supported upon knife edges five inches apart. A load

was applied at a point midway between the supports by suspending a pail from a yoke having a knife edge which rested upon the bar at that point. Into this bucket a stream of sand was permitted to flow until the weight of the pail and sand was sufficient to break the bar.

The result of the test was expressed as the Modulus of Rupture, which was calculated as follows:

$$\text{Modulus of rupture} = \frac{3 \times \text{weight in lbs.} \times \text{distance between supports}}{2 \times \text{Breadth} \times \text{Depth}^2}$$

The breadth and depth of the bars were determined by measuring the bars before breaking.

Ordinarily ten bars were tested, and the average of eight or nine taken.

BONDING TEST.

The test pieces are made of equal parts of clay and standard sand that passes a twenty mesh (0.0328 inch hole, 0.0172 inch wire) and is retained on a twenty-eight mesh (0.0232 inch hole, 0.0125 inch wire) standard sieve. This mixture was wet with water and thoroughly worked until brought to a suitable consistency.

The preparation of the test pieces, the conditions of drying and the method of breaking were similar to the methods described under "Transverse Tests."

BURNING TESTS.

The test pieces prepared in the form of bars for drying shrinkage were burned in a laboratory kiln and studied with reference to the changes in shrinkage, porosity, color and hardness brought about at various temperatures.

The laboratory kiln used was of the down-draft type with a chamber capacity of approximately twenty-seven cubic feet. It was coal fired and the normal rate of firing was:

Room temperature to 750° F. in 4 hours.
750° F. to 1,290° F. in 6 hours.
1,290° F. to 1,370° F. in 3 hours.
1,370° F. to 1,850° F. in 2 hours.
1,850° F. up at rate of 35° F. per hour.

The trial pieces were placed in closed saggers (*i. e.*, fireclay boxes) in order to protect them from contact with the flames, and flying ashes.

A separate burn was made to each of four different temperatures, namely, those corresponding to pyrometric cones 2, 5, 9, 12, or approximately 2138° F., 2246° F., 2390° F., 2498° F.

After burning, the shrinkage was determined by measuring the distance between the marks previously made on the piece for the drying shrinkage. The porosity was determined by measuring the volume of water absorbed under a vacuum and comparing this with the total volume of the piece. The procedure was to weigh the cooled test piece, place it in a closed receptacle filled with distilled water and connected with a vacuum pump which could maintain a vacuum of twenty-nine inches. The piece was left in the vacuum for three hours. At the end of that time it was removed, the surface of the test piece wiped dry and weighed. The amount of increase of weight due to the absorption of water represented the open pore space. The total volume of the piece was measured in a volumenometer. This apparatus consists of a large size glass bottle with a wide neck ground so that a glass cap fits it securely. A side tube connects the bottle with a burette or graduated glass tube. The apparatus is filled to a certain point with water and the displacement due to the introduction of the test piece may be measured directly upon the burette which gives the volume of displacement or, in other words, the volume of the test piece. The calculation of porosity becomes

Saturated weight — dry weight = weight of water absorbed.

Weight of water absorbed = volume of water absorbed.

Volume of water absorbed = volume of pores.

$$\frac{\text{Volume of pores}}{\text{Volume of whole piece}} \times 100 = \text{per cent porosity.}$$

Color changes are described for each test piece at each temperature.

Hardness was determined by noting the ease or difficulty experienced in scratching the trial pieces with the point of the knife.

Fusion or deformation tests were made by molding the clay into the form of a standard cone—that is, a three-sided pyramid or tetrahedron 0.23 inches along the edges of the base and 1.2 inches high. These were set in a support of refractory material so that the bases of the cones were only slightly imbedded. With these trial pieces were placed standard pyrometric cones and the whole was burned in a furnace to a high temperature. Two furnaces were used. One was the ordinary Fletcher furnace, which was used for temperatures

up to 3038° F. This furnace uses gas with compressed air to generate the temperature. For higher temperatures, a Deville furnace was used. This furnace is operated by the combustion of coke by means of a low pressure air blast. No difficulty was experienced in

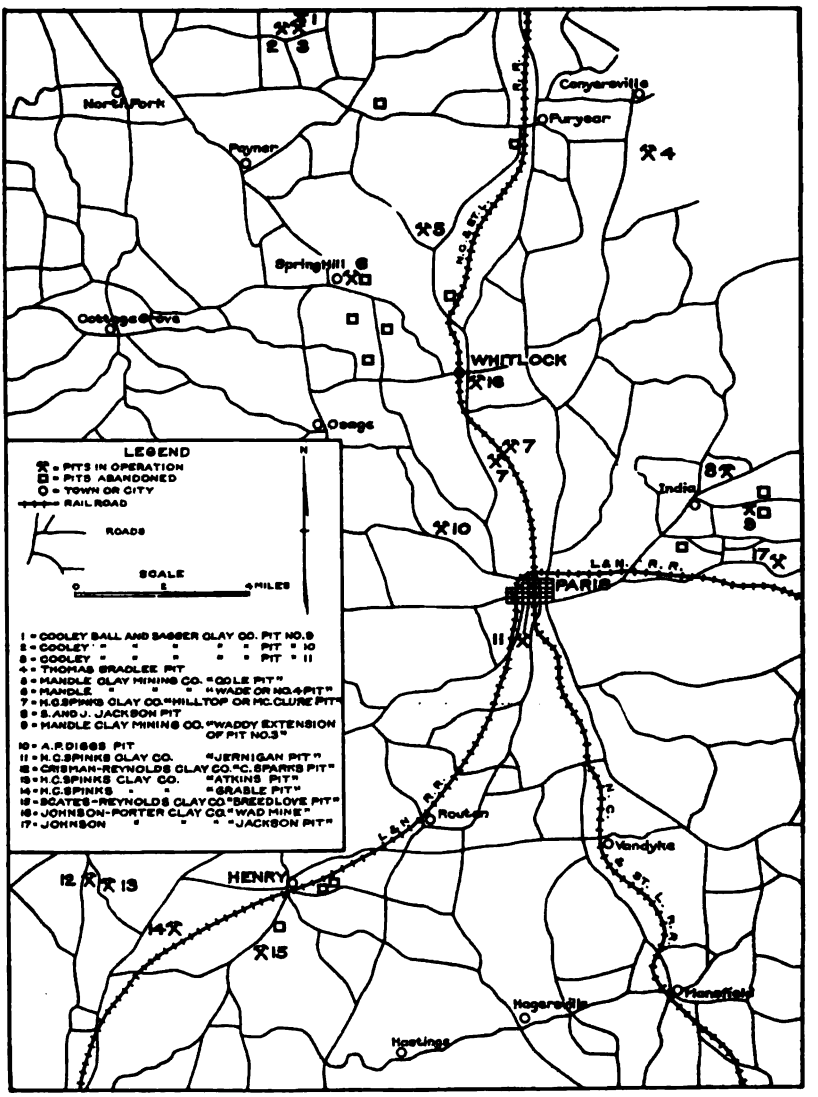
North Fork
Conyersville
Puryear
Paynes
Spring Hill
Cottage Grove
WHITLOCK
Osage
India
PARIS
L & N. R. R.
Routon
Vandyke
HENRY
Hagersville
Hastings
Hensfield
LEGEND
PITS IN OPERATION
PITS ABANDONED
TOWN OR CITY
RAIL ROAD
ROADS
SCALE
MILES
1 = COOLEY BALL AND SAGGER CLAY CO. PIT NO.9
2 = COOLEY " " " " " PIT " 10
3 = COOLEY " " " " " PIT " 11
4 = THOMAS BRADLEE PIT
5 = MANDLE CLAY MINING CO. "COLE PIT"
6 = MANDLE " " " "WADE OR NO.4 PIT"
7 = H.C.SPINKS CLAY CO. "HILLTOP OR MC.CLURE PIT"
8 = S.AND J. JACKSON PIT
9 = MANDLE CLAY MINING CO. "WADDY EXTENSION OF PIT NO.3"
10 = A.P.DIGGS PIT
11 = H.C.SPINKS CLAY CO. "JERNIGAN PIT"
12 = CRISMAN-REYNOLDS CLAY CO. "C. SPARRS PIT"
13 = H.C.SPINKS CLAY CO. "ATKINS PIT"
14 = H.C.SPINKS " " "GRABLE PIT"
15 = BOATES-REYNOLDS CLAY CO "BREEDLOVE PIT"
16 = JOHNSON-PORTER CLAY CO. "WAD MINE"
17 = JOHNSON " " " "JACKSON PIT"

FIGURE 6—Map of Henry County, showing distribution of clay pits.

bringing about the fusion of cone thirty-two, which corresponds to a temperature of about 3218° F.

A test piece is considered fused when it has softened sufficiently to bend over so that the tip touches the base on which the cone is supported. A similar condition of one of the standard pyrometric cones would indicate the temperature at which this had taken place.

Local Descriptions and Results of Tests.

HENRY COUNTY.

Topography.—This county has an area of 625 square miles. The Tennessee-Mississippi River divide crosses the middle of the county in a direction somewhat east of north. The surface along this divide

FIGURE 7—Grable Pit, near Henry, H. C. Spinks Clay Company.

is rough and broken. On the east it has a relatively steep slope characterized by numerous large and deep gullies, which are eroded headward very rapidly and often make it necessary for roads and houses to be moved to prevent their complete destruction. Stream activity on this side of the divide is more marked than on the other side. West of the divide the general surface has a considerable slope, but soon flattens out into a nearly level plain that stretches westward to the Mississippi bluffs. The greatest elevation is about 600 feet in the northwestern part of the county, and the least 300 feet at the point where the Tennessee River leaves the State. The average elevation is about 500 feet.

HENRY COUNTY PITS.

The H. C. Spinks Clay Co., of Newport, Ky., operates four pits in this county.

Grable Pit.—This pit is situated on the Louisville & Nashville Railroad, two miles west of Henry. It is forty-five feet deep and occupies about two acres. (See Fig. 7.) It is reached by means of an inclined railway 250 feet long, which connects with the Louisville & Nashville Railroad. The angle of slope is about 15° and the clay is hauled up from the pit in dump cars to the sheds at the surface.

Wad, sagger and ball clays are mined here. The clay underlies a hill of ten acres area, the top surface of the clay body dipping with the slope of the hill. The following section was exposed in the pit:

Section at Grable Pit.

Red, clayey sand	10 feet
Grey, sandy clay (wad clay)	30 inches
Brown to dark grey, plastic clay (sagger clay), containing leaf impressions. This clay was sampled (No. 38 S)	20 feet
Pale yellow to pink, very plastic clay, free from grit. This clay was sampled (No. 39 S)	3 feet
Dark, sandy clay (wad clay)	5 feet
Red sand	Exposed to bottom of pit

The dark clays in this pit are rich in beautiful fossil leaf impressions. Some specimens retain the carbonaceous remains of the leaf itself. This, when dry, curls up, powders and vanishes unless protected with a thin coat of shellac. The estimated tonnage in the bank of the twenty feet stratum of sagger clay is 459,700; of the ball clay stratum, 72,600.

Result of Tests.

No. 38 S.—This clay is not deformed at cone twenty-eight, slakes in six and one-half minutes and burns dark cream.

No. 39 S.—This clay is not deformed at cone twenty-eight, slakes in six minutes and burns dark buff.

A preliminary test only was made on these clays, complete tests having been made only on clays that seemed promising as *highly refractory bond clays*, such as are used in the manufacture of glass-pots and crucibles (in demand by our government as a war mineral). The Survey hopes to make additional tests on these samples.

Hilltop Mine or McClure Pit.—This pit is operated by H. C. Spinks Clay Co., of Newport, Ky. It is situated four miles north of Paris on the Nashville, Chattanooga & St. Louis Railway. The pit is on the east side of the track, but the clay extends under the track, and

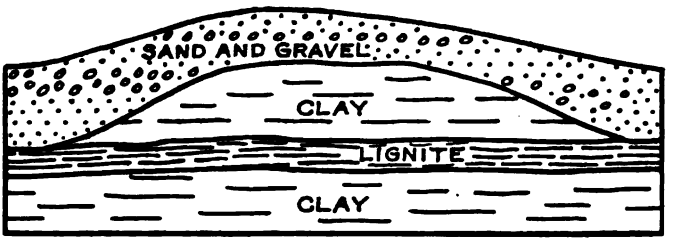

FIGURE 8—Geologic profile section in Hilltop Mine, south of Whitlock, showing unconformable relations of clay and overburden.

preparations were being made to open an extension on the west side at the time this pit was visited. The following section was noted:

Section at Hilltop Mine.

Orange and red, case-hardened sands with cherty gravel and ironstone concretions, containing small clay pellets	10-12 feet
Local unconformity.	
Hard-pan stratum	2 inches
Clay, white with pink blotches and streaks, slightly sandy (sagger clay)	6 feet
Clay, brown, lignitic, sandy (sagger clay)	4 feet
Lignitic clay	1½ feet
Ball clay, greyish-blue and pale brown (sample No. 40 S)	2 feet
Lignitic clay	1 foot
Ball clay, grey (sample No. 40 S)	3 feet
Ball clay, dark brown to greenish black, is said to burn pale greenish color (sample No. 46 S)	3-5 feet
Clay, pale yellow-brown, very plastic, not much grit (sample No. 47 S)	4 feet
White sand	2+ feet

The clay is mined by hand and hauled up a steep incline by mule teams and loaded at a switch at the surface. Several acres of clay are available. Figure 8 shows the unconformable relations between the clay deposit and the overburden.

Result of Tests.

No. 40 S.—This clay is not deformed at cone twenty-eight, slakes in five minutes and burns to a dark cream color.

No. 47 S.—This clay is not deformed at cone twenty-eight and slakes in five minutes.

A preliminary test only was made on these clays, complete tests having been made only in cases where the clay seemed promising as a *highly refractory bond clay* such as is used in the manufacture of glass-pots and crucibles (in demand by our government as a war mineral). The Survey hopes to make additional tests on this sample.

No. 46 S.—This test was made at the Ceramic Laboratory of the University of Illinois, under the direction of Prof. Cullen W. Parmelee:

Sample No. 46 S.

Received from Tennessee Geological Survey.

Collected by R. A. S.

Locality—H. C. Spinks Clay Co. Hill Top Mine on Whitlock-Paris Road. Below grey ball clay and above yellow clay stratum.

Kind of Material—A brown-colored clay of fairly uniform character excepting for slight light brown stains. A small amount of mica is present.

Working property—Good.

Water necessary to develop plasticity—44.2 per cent.

Strength of unburned clay—Cross-breaking test. Modulus of rupture = 230.9 pounds per square inch.

Bonding strength with equal parts of standard sand. Modulus of rupture = 93 pounds per square inch.

Slaking test—70 minutes.

Fineness test:

20-mesh sieve	0.14% residue
40-mesh sieve	0.11% residue
60-mesh sieve	0.19% residue
80-mesh sieve	0.12% residue
120-mesh sieve	0.42% residue
200-mesh sieve	0.82% residue

Drying shrinkage, linear = 5.4 per cent.

Burning conduct:

	Color	Hardness	Total Shrinkage	Porosity
Cone 2	White	Not steel hard	11.0%	38.2
Cone 5	Light cream	Steel hard	16.2%	17.4
Cone 9	Light grey	Steel hard	15.6%	14.6
Cone 12	Light grey	Steel hard	17.2%	4.7

Fusion test: Deforms at Cone 32.

This clay burns to a good color at cone nine; its strength when unburned is good. It burns rather open at cone nine, but it will find some use as a ball clay. It has a rather high fusion test and probably

will serve where a refractory plastic clay is required, in the manufacture of certain wares. It will serve in the manufacture of sanitary wares, chemical stoneware, stoneware saggers and abrasives.

Jernigan Pit.—This pit is operated by the H. C. Spinks Clay Co., of Newport, Ky. It is leased from T. P. Jernigan and is situated one mile south of Paris. It was opened in June, 1918, and the overburden was being stripped at the time the pit was visited. The pit lies on the west side of a rather steep, wooded hill and is nicely drained by several deep gullies. The clay is hauled by team to Paris. The equipment comprises six wheelers, three scoops, eleven mule teams and a crew of twenty men.

The following section was noted:

Section at Jernigan Pit.

Sand, brown and clayey	0-20 feet
Unconformity	
Clay, white, very sandy, not used	4 feet
Clay, white, plastic and free from sand, containing limonitic spots	1 foot
Clay, brown, plastic, slightly sandy, with occasional yellow stains. It is poorly stratified, containing fossil leaf impressions, and is traversed by vertical joint planes. Thickens towards the northwest. Sample No. 53 S	4-20 feet
Clay, dark olive green, plastic, free from grit. It is traversed by a system of vertical joint planes, along which the clay has weathered to a pinkish brown to a depth of 2 to 3 inches. Contains small amounts of limonite in places. It is said that this clay bleaches white after mining. It is sold as ball clay and is known as No. 9. This clay stratum pinches out toward the west. Sample No. 54 S	3-9 feet
Clay, pinkish grey, very plastic. The upper part of this bed is sold as ball clay. It contains thin strata of yellow, limonitic sand towards the base. Pinches out towards the west, but is said to thicken to nine feet 300 yards towards the northeast. Sample No. 55 S	4 feet
White sand	

Result of Tests.

Sample No. 53.—This clay is not deformed at cone twenty-eight and slakes in five minutes.

Sample No. 54.—This clay is not deformed at cone twenty-eight and slakes in six minutes.

Sample No. 55.—This clay is not deformed at cone twenty-seven and slakes in nine minutes.

A preliminary test only was made on these clays, complete tests having been made only in cases where the clay seemed promising as *highly refractory bond clay* such as is used in the manufacture of glass-pots and crucibles (in demand by our government as a war mineral). The Survey hopes to make additional tests of these samples.

Atkins Pit.—This pit is operated by H. C. Spinks Clay Co., of Newport, Ky., and is situated two miles northwest of the Grable Pit, to which point the clay is hauled by teams. It is a small pit in the early stages of development. The clay underlies a hill of about three acres area. The top surface of the clay body dips with the slope of the hill and a spring emerges from it at the pit. The following section was noted:

Section at Atkins Pit.

Sand, pale orange and brown	10-20 feet
Ball clay, rose, exceedingly tough and plastic; too sticky to be worked	8 inches
Lignitic clay (contains marcasite concretions) not present towards north, 4 feet thick towards south	1 foot
Ball clay, dark greenish grey, contains fossil leaves and nuts (Sample No. 52 S)	9 feet
Clay, white, very tough	1 foot
Clay, white, sandy (wad clay)	2 feet
White sand (depth not ascertained)	

Fossil leaves are found here in great abundance and perfection and of large size (up to one foot long). Two fossil nuts were found here by Mr. Spinks and presented to the writer. They were submitted to Edward W. Berry of Johns-Hopkins University for identification. He has the following to say regarding them: "The fossils proved of exceptional interest. While somewhat unlike in appearance, they appear to represent the results of compression in different planes, and as they are alike under the microscope I take them to represent the same species. It is unique and I have never seen anything like it in the South. It belongs to a genus known as *Monocarpellites* (one-celled, several-seeded nuts of not certainly determined botanical affinity), and is apparently a new species. The only other known occurrence of the genus is in the lignites at Brandon, Vermont, usually regarded as Miocene, but for whose Eocene age I have argued on several occasions. I assume they came from your Lagrange formation and are of Wilcox (Eocene) age."

The specimens will be placed in the U. S. National Museum. As Mr. Berry's assumption is correct, they may prove of value in correlating the Brandon lignites with the Lagrange of West Tennessee.*

Result of Tests.

No. 52 S.—This clay is not deformed at cone twenty-eight and slakes in five minutes.

A preliminary test only was made on this sample, complete tests having been made only on clays that seemed promising as *highly refractory bond clays,* such as are used in the manufacture of glass-

FIGURE 9—Wade, or No. 4, Pit near Whitlock, Mandle Clay Mining Co.

pots and crucibles (in demand by our government as a war mineral). The Survey hopes to make additional tests on this sample.

Wade or No. 4 Pit.—This pit is leased from P. A. Wade by the Mandle Clay Mining Co., of St. Louis. It is situated three and one-half miles northwest of Whitlock and is connected with the Nashville, Chattanooga & St. Louis Railway at that place by means of a dinky line. The pit is one of the largest in the State, covering four acres. (See Fig. 9.) It is located on the north side of a low prominence under which the clay lies. Borings show twenty acres of clay available. The overburden is forty-five feet thick and is removed by steam shovel. The equipment comprises three fifteen-ton locomotives, thirty

*See Berry, Edward W., Age of the Brandon Lignite and Flora, Am. Jour. of Science, Vol. XLVII, art. 13, March, 1919.

cars, one steam shovel and a crew of fifty-five men. The sands and clay are removed by blasting with dynamite and the use of picks and shovels. The clay deposit occupies a large bowl-shaped depression

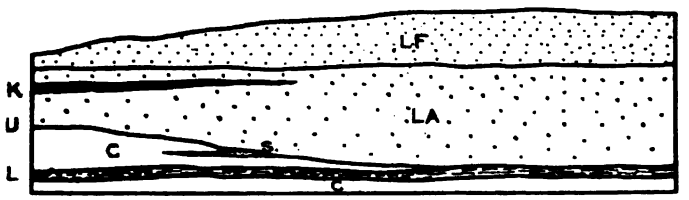

FIGURE 10—Geologic profile section in Wade Pit near Whitlock, showing unconformable relations of clay and overburden.

and is unconformable with the overburden. (See Fig. 10.) The following section was noted:

Section at Wade Pit.

Lafayette—Massive, red and red-brown sands, case-hardened. In removing this stratum with steam shovel it is undermined and slumps off in huge blocks ..... 10-15 feet

Lagrange—Sand, pale brown and cream, streaked with pink, yellow and purple. Contains large ironstone concretions with cores of pyrite (in various stages of decomposition), quartz grains with green iron coating and clay pellets. Also contains a two-foot stratum of hard, indurated kaolinite (pink in color and impure). This stratum is thickest at the south end of pit and pinches out towards north. The kaolinite burns to a pale grey color but is siliceous and non-plastic. Thickness of Lagrange over clay is..... 30 feet

Disconformity.

Clay, white and sandy; present at extreme north and south ends of pit; has been eroded in intervening space..... 0-12 feet

Lignitic clay ..... 4-5 feet

Clay—Tennessee Ball Clay No. 5. Chocolate brown to grey, exceedingly free from iron and grit. Somewhat lignitic especially near top. The organic matter burns out. It is massive and has a greasy feel. The overlying lignite grades into this clay. The color of the clay is lighter towards the base. (See test A)..... 4½ feet

Lignitic clay, very dark in color ..... 8 inches

Clay—Tennessee Ball Clay No. 4, dark grey and brown, not very plastic unless moist, massive, greasy and somewhat woody. Contains occasional rootlets. Is used for glass-pots. Stands cone No. 36. (See test B) ..... 30 inches

Lignitic clay ..... 8 inches

Clay, known as "pink No. 1 W. W. C.," putty grey with claret streaks and blotches, very plastic at top. The bottom is not so plastic and is discolored by iron and is graded as "No. 4 B. G." This stratum pinches out towards the south. The top is locally known as "gumbo." (See test D) ..... 7½ feet

Clay, known as "No. 1 S. G. P. Ball Clay," simply another phase of the same stratum. It is grey, plastic and free from sand. It becomes pink towards the north, where it is graded as "No. 1 W. W. C." (See above.) (See test C.) ..... 5½ feet

Clay, known as "A No. 2," light grey, stained rose, slightly sandy. (See test E.) ..... 2½ feet

Clay, known as "Sagger No. 2," pale grey, thickest at center of pit. (See test F.) ..... 0-10 feet

Sand, white and sugary .....

The accompanying tests were kindly submitted by the Mandle Clay Mining Co., of St. Louis:

Test A—Tennessee Ball Clay No. 5.[1]

Unwashed sample. Volatile matter records free and combined water as well as impurities in the form of lignite.

Analysis.

Volatile	16.45
Silica	46.85
Alumina	33.15
Iron oxide	2.04
Calcium	.35
Magnesium	.40
Potassium	.61
Sodium	.10
Sulphur	.03

Porosity Chart.

Temp. Degrees	Porosity Per cent
1,050 C.	35.48
1,075 C.	26.55
1,100 C.	19.03
1,125 C.	16.50
1,150 C.	13.90
1,175 C.	9.00
1,200 C.	3.77
1,230 C.	2.29
1,260 C.	2.28
1,290 C.	1.17
1,320 C.	2.15
1,350 C.	1.14
1,375 C.	1.80
1,400 C.	0.82
1,425 C.	1.39
1,450 C.	2.85
1,475 C.	3.80
1,500 C.	5.18

[1]This test was made by the Bureau of Standards, Pittsburgh.

	F.°	C.°	Cone
Fusing point	3,272	1,800	32½
Vitrifies	2,147	1,200	3¼

The average cross-breaking modulus in pounds per square inch determined from tests made on 12 bars in dried condition 387
Time of slaking in water, ⅞-inch dried cube ..... 27 minutes
Water of plasticity 44.73%

Linear Shrinkage.

From room temperature and leather hard to 110 degrees C.:
5.57% to 110 degrees C.
14.57% maximum in fire

20.14% total shrinkage

Maximum shrinkage is reached at 1,210 degrees C.

In fire after drying to 110 degrees C.

Degrees	
1,050 C.	2.60%
1,125 C.	7.63%
1,200 C.	10.75%
1,320 C.	14.57%

Test B—Tennessee Ball Clay No. 4.[1]

Analysis No. 1 made in 1915. Unwashed sample.		Analysis No. 2 made in 1917. Unwashed sample.	
Volatile	15.30	Volatile	17.30
Silica	44.50	Silica	42.50
Alumina	35.43	Alumina	35.40
Iron oxide	3.25	Iron oxide	3.22
Calcium	.34	Calcium	.34
Magnesium	.42	Magnesium	.43
Potassium	.62	Potassium	.65
Sodium	.10	Sodium	.12
Sulphur	.04	Sulphur	.04
	100.00		100.00

	F.°	C.°	Cone
Fusing point	3,327	1,830	35½
Vitrifying point	2,147	1,175	2¼

(Bureau of Standards test.)

The average cross-breaking modulus in pounds per square inch determined from test made on 12 bars in dried condition 344
Time of slaking in water, ½-inch dried cube ..... 12½ minutes
Water of plasticity 42.90%

[1]This test was made by the Bureau of Standards, Pittsburgh.

Linear Shrinkage.

From room temperature and leather hard to 110° C.:	Degrees	
5.57%	1,050 C.	2.60%
14.57% Max. shrinkage in fire	1,125 C.	7.63%
	1,200 C.	10.75%
20.14 Total shrinkage	1,320 C.	14.57%
Maximum shrinkage reached at 1,210° C.		

Porosity Chart.

Temp. Degrees	Porosity Per cent
1,050 C.	42.80
1,075 C.	41.85
1,100 C.	38.75
1,125 C.	36.00
1,150 C.	18.83
1,175 C.	14.65
1,200 C.	14.17
1,230 C.	9.38
1,260 C.	3.79
1,290 C.	.33
1,320 C.	.32
1,350 C.	1.52
1,375 C.	1.81
1,400 C.	1.45
1,425 C.	1.31
1,450 C.	.82
1,475 C.	1.49
1,500 C.	5.27

No. 4 Ball is similar to the No. 5 Ball Clay in a good many respects, but it is not as strong in the green state, nor is its color nearly as good after burning. The difference of the iron content indicates this. However, the refractory properties of the No. 4 is abnormally high, as is also the alumina content.

Test C—Tennessee Ball Clay No. 1 S. G. P.

Analysis made in 1910. Unwashed sample.

Volatile	10.92
Silica	33.13
Alumina	32.32
Iron oxide	1.31
Calcium	.62
Magnesium	.38
Potassium	.59
Sodium	.21
Sulphur	.02
	100.00

	F.°	C.°	Cone
Fusing point	3,238	1,770	32
Vitrifying point	2,246	1,230	5

The average cross-breaking modulus in pounds per square inch determined from tests made on 12 bars in dried condition 303
Time of slaking in water ½-inch dried cube ..... 12.6 minutes
Water of plasticity 44%

Linear Shrinkage.

From room temperature and leather hard to 110 degrees C.:
5.50%
12.00% Maximum in fire reached at 1,230 degrees C.

In fire after drying to 110 degrees C.
1,230° C. 12.00%

17.50 Total shrinkage

Tennessee Ball Clay No. 1 S. G. P. is for the most part a dark grey clay, though it varies somewhat in color. It is sold by the Mandle Clay Mining Co. to white ware, tile and electric porcelain makers.

Test D—Tennessee Ball Clay No. 1 W. W. C.

Analysis made in 1910. Unwashed sample.

Volatile	13.43
Silica	47.26
Alumina	35.85
Iron oxide	1.01
Calcium	.58
Magnesium	.68
Potassium	.74
Sodium	.45
Sulphur	.00

	F.°	C.°	Cone
Fusing point	3,254	1,790	33
Vitrifying point	2,282	1,250	6

The average cross-breaking modulus in pounds per square inch, determined from tests made on 12 bars in dried condition 279
Time of slaking in water, ½-inch dried cube..... 14 minutes
Water of plasticity 45%

Linear Shrinkage.

From room temperature and leather hard to 110 degrees C.:
5.50%
11.56% Maximum shrinkage in fire, reached at 1,250 degrees C.

In fire after drying to 110 degrees C.:
1,250° C. 11.58%

17.06% Total shrinkage

The Tennessee Ball No. 1 W. W. C. is the choicest of the light clays mined by us. It has a very light gray and pinkish color.

Test E—Tennessee Ball Clay A No. 2.

A No. 2 Ball clay is a uniform smooth-whittling and plastic refractory clay, and is used extensively where clay of this nature is required, principally in the manufacture of potters' supplies, such as stilts and pins, and also in magnesia ware, such as gas mantles, plates on burners for electric stoves, etc. When fired this clay is very strong and of a splendid color.

Test F—Tennessee Sagger Clay No. 2.

No. 2 Sagger clay comes from the bottom of Mine No. 4, and is a very clean and uniform clay of pinkish and white color. It stands a very high heat and makes an excellent Sagger for the higher heats, such as cone ten and twelve. While this clay is very strong after being fired, its semi-open nature prevents cracking both in the drying and in the firing. An important feature of this and our other Sagger clays is their uniformity and cleanliness and low iron content.

Cole Pit.—This pit is operated by the Mandle Clay Mining Co., of St. Louis, and is situated two and one-half miles southwest of Puryear. The clay in this pit is all sold as wad. It is very plastic, sandy and stratified. It is mined by hand and carted three-fourths of a mile to a spur on the Nashville, Chattanooga & St. Louis Railway situated midway between Whitlock and Puryear. The pit is small but the clay deposit is said to underly twelve acres. The dark clays in this deposit bear fossil leaf prints. A spring emerges from the surface of the clay. The following section was observed:

Section at Cole Pit.

Lafayette—Red, massive sands, very rich in gravel towards base	12 feet
Lagrange—Yellow, cream and brown sands containing a pink mass of sandy clay near base	8-12 feet
Hard-pan	1 inch
Clay, grey, plastic and sandy, with yellow stains near top (see test A)	6-8 feet
Clay, dark grey, plastic and sandy in lower portions. This is the best clay in the pit and is said to merge into a ball clay towards the north. Pinches out towards south (see test B)	6-10 feet
Clay, pale grey, very plastic, sandy	3-4 feet
Clay, cream to pinkish, sandy, fibrous fracture	3 feet
Clay, rusty and sandy	2 feet
White sand	

The accompanying tests were kindly submitted by the Mandle Clay Mining Co., of St. Louis, Mo. This test was made by the Bureau of Standards, Pittsburg.

Test A—Special Selected Light Clay.

Analysis made in 1908. Unwashed sample.

Volatile	8.00
Silica	64.30
Alumina	24.60
Iron oxide	1.56
Calcium	.43
Magnesium	.55
Potassium	.42
Sodium	.10
Sulphur	.04
	100.00

	F.°	C.°	Cone
Fusing point	3,182	1,750	31

Open burning clay. Lowest porosity 0.65%, reached at 1,475° C.

Average cross-breaking modulus in pounds per square inch, determined from tests made on 12 bars in dried condition 285

Time of slaking in water, ½-inch dried cube ..... 8.6 minutes

Water of plasticity 30.27%

Linear Shrinkage.

From room temperature, and leather hard to 110° C.:	
5.46%	
4.74%	Maximum shrinkage in fire
10.20%	Total shrinkage

In fire after drying to 110 degrees C.:	
Degrees	Per cent
1,050 C.	0.27
1,125 C.	3.18
1,200 C.	4.12
1,320 C.	4.74

The Special Selected Light Clay behaves very similar to the Special Selected Black Clay in the fire, except that it overburns more gradually. Both clays have practically reached fusing point before overburning begins. The light clay is the stronger of the two in the fired state. Hence it may be advantageous to use a combination of the two clays. The Special Selected Light Clay is a very clean and uniform clay.

Test B—Special Selected Black Clay.

Analysis No. 1, made in 1908. Unwashed sample.		Analysis No. 2, made in 1917. Unwashed sample.	
Volatile	8.80	Volatile	8.00
Silica	61.02	Silica	65.43
Alumina	26.32	Alumina	22.65.
Iron oxide	1.38	Iron oxide	2.00
Calcium	.69	Calcium	.50
Magnesium	.72	Magnesium	.70
Potassium	.65	Potassium	.55
Sodium	.18	Sodium	.14
Sulphur	.04	Sulphur	.03
	100.00		100.00

	F.°	C.°	Cone
Fusing point	3,182	1,750	31

Open burning clay. Lowest porosity 0.66%, reached at 1,475° C.
Average cross-breaking modulus in pounds per square inch, determined from tests made on 12 bars in dried condition 466
Time of slaking in water, ½-inch dried cubes ..... 12½ minutes
Water of plasticity 30.75%

Linear Shrinkage.

From room temperature, and leather hard to 110 degrees C.:		In fire after drying to 110 degrees C.: Degrees	
5.93%		1,050 C.	0.25%
4.63%	Maximum shrinkage in fire	1,125 C.	2.21%
		1,200 C.	2.08%
10.56%	Total shrinkage.	1,320 C.	4.63%

The Special Selected Black Clay has great strength in the green state and unusually fine plastic properties and is a good bonding clay even though silicious.

Pit No. 3 or Waddy Extension.—This is operated by the Mandle Clay Mining Co., of St. Louis., and is an extension of the exhausted Claxton Pit. It is situated one mile northeast of India. The pit is about one acre in area and is being worked towards the north under a hill which separates it from the old Claxton (No. 3) Pit.

Section.

Sand, red and massive	3 feet
Sand, brown, red and cream, well bedded	8 feet
Lignitic clay thickest at east end of pit, not present south end	1 foot

Sand and clay bed, showing contemporaneous erosion of the clay. The sand is grey, coarse and micaceous and contains intraformational fragments of a similar colored clay. At one end of the pit this clay underlies the sand *in situ* with an unconformable upper surface but thickens to the north, finally replacing the sand entirely and is said to develop into an eight-foot stratum of sagger clay under the hill. (Commercially known as "Special Sagger Clay" and "Tennessee Glass Pot Clay")	5 feet
Lignitic clay, containing pyrite (or marcasite) nodules, thickest on north side	2 feet
Ball clay, dark brown and blue-grey, known as "Tenn. Ball Clay No. 3," contains rootlets and lignitic matter in upper parts	5-6 feet
Clay,* lignitic	18 inches
Clay,* black, contains organic matter	2 feet
Clay,* blue-grey, wet and sandy in places, known as Tenn. Ball No. 6	2 feet

The following tests were kindly submitted by the Mandle Clay Mining Co.:

Special Sagger Clay.

This clay is in many respects like the glass pot clay, such as fusibility, tensile strength, etc. However, it is not so uniform and more siliceous.

Tennessee Glass Pot Clay.[1]

Analysis No. 1, made in 1908. Unwashed sample.		Analysis No. 2, made in 1917. Unwashed sample.	
Volatile	8.38	Volatile	12.00
Silica	63.54	Silica	63.45
Alumina	24.42	Alumina	20.45
Iron oxide	1.22	Iron oxide	1.85
Calcium	.60	Calcium	.50
Magnesium	.63	Magnesium	.55
Potassium	1.00	Potassium	.70
Sodium	.15	Sodium	.14
Sulphur	.06	Sulphur	.06
	100.00		100.00

	F.°	C.°	Cone
Fusing point	3,113	1,729	30

Open burning clays. Lowest porosity 1.23%, reached at 1,425° C.

Cross-breaking modulus average in pounds per square inch, determined from tests made on 12 bars in dried condition ..... 407 lbs.

Tensile strength, direct pull test, fired to cone 8 ..... 1,055 lbs.

*These beds were concealed by water at the time the pit was visited and hence were not measured. The description was furnished by Mr. Mandle.

[1]This test was made by the Bureau of Standards, Pittsburgh.

Time of slaking in water, ½-inch dried cube.....12 minutes
Water of plasticity 29.02%

Linear Shrinkage.

From room temperature, and leather hard to 110 degrees C.:
5.48%
4.82% Max. shrinkage in fire
10.30% Total shrinkage

In fire after drying to 110 degrees C.:

Degrees	
1,050 C.	0.50%
1,125 C.	2.87%
1,200 C.	4.09%
1,320 C.	4.82%

Porosity Chart.

Temp. Degrees	Porosity Per cent
1,050 C.	33.86
1,075 C.	32.55
1,100 C.	29.84
1,125 C.	27.88
1,150 C.	24.67
1,175 C.	22.60
1,200 C.	20.13
1,230 C.	19.07
1,260 C.	18.10
1,290 C.	17.92
1,320 C.	15.09
1,350 C.	10.72
1,375 C.	4.92
1,400 C.	3.10
1,425 C.	1.23
1,450 C.	17.40
1,475 C.	17.72
1,500 C.	22.21

It will be noted that Tenn. Glass-Pot Clay is a siliceous clay, but has splendid strength in the green and fired state, and while it is an open burning clay, it nevertheless has a fairly high fusing point and does not begin to overburn much below same.

Tennessee Ball Clay No. 3.[1]

Analysis made from unwashed sample.

Volatile	14.50
Silica	48.15
Aluminum	32.35
Iron oxide	2.25
Calcium	.60
Magnesium	.54
Potassium	.92
Sodium	.12
Sulphur	.17

Porosity Chart.

Temp. Degrees	Porosity Per cent
1,050 C.	37.50
1,075 C.	28.70
1,100 C.	20.75
1,125 C.	16.95
1,150 C.	16.48
1,175 C.	13.90
1,200 C.	3.46
1,230 C.	3.46
1,260 C.	2.45
1,290 C.	0.98
1,320 C.	2.34
1,350 C.	1.99
1,375 C.	1.89
1,400 C.	3.02
1,425 C.	3.22
1,450 C.	4.45
1,475 C.	4.67
1,500 C.	5.80

Fusing point, cone 32 plus.
Vitrifying point, 1,230 degrees C.

[1]This test was made by the Bureau of Standards, Pittsburgh.

The average cross-breaking modulus in pounds per square inch, determined from tests made on 12 bars, dried 326
Time of slaking in water, ⅞-inch dried cube ..... 18½ minutes
Water of plasticity 46.10%

Linear Shrinkage.

From room temperature and leather hard to 110 degrees C.:
55%
Total shrinkage, 19.05%

In fire after drying to 110 degrees C.:

Degrees	
1,050 C.	2.50%
1,125 C.	6.65%
1,200 C.	9.75%
1,320 C.	13.50

Tennessee Ball Clay No. 6 (Refractory).

Analysis made in 1908. Unwashed sample.

Volatile	13.16
Silica	51.57
Alumina	30.40
Iron oxide	2.10
Calcium	.60
Magnesium	1.25
Potassium	.68
Sodium	.14
Sulphur	.10
	100.00

	F.°	C.°	Cone
Fusing point	3,218	1,770	32

Overburning clay. Lowest porosity 0.35, reached at 1,370 degrees C.
The average cross-breaking modulus in pounds per square inch, determined from tests made on 12 bars in dried condition 360
Time of slaking in water, ½-inch dried cube ..... 12½ minutes
Water of plasticity, 40%.

Linear Shrinkage.

From room temperature and leather hard to 110 degrees C.:
5.55%
13.50% Maximum shrinkage in fire reached at 1,370 degrees C.

19.05% Total shrinkage

In fire after drying to 110 degrees C.:
1,370° C. 13.50%

Tennessee Ball Clay No. 6 is a smooth, oily clay of beautiful appearance in the green state, and but for its open-burning would be a splendid ball clay. However, its refractoriness and plasticity make it a splendid clay for many purposes.

Pit No. 9 of the Cooley Ball & Sagger Clay Co., of Hazel, Ky.— This pit is situated five and one-half miles west of Hazel, Ky., just south of the Kentucky-Tennessee line.

The following section was seen at the pit:

Section at Pit. No. 9.

Red, clayey sand and gravel with occasional strata of hard-pan	12 feet
Yellow sand	4 feet
Hard-pan conglomerate, with cherty pebbles up to two inches diameter	1-14 inches
Ball clay, grey with pink blotches (the discoloration especially marked in upper portions) with a few red iron concretions near top (sampled for testing as No. 9, White ball)	7-14 feet
Sagger clay, grey	2 feet
Sand, pale grey and coarse	

The accompanying tests were made at the Ceramic Laboratory of the University of Illinois, under the direction of Prof. Cullen W. Parmelee:

Sample No. —, White ball clay, Mine No. 9.

Received from Cooley Ball & Sagger Clay Co.

Locality—Five miles west of Hazel, Ky.

Kind of Material—Light, cream-colored, plastic clay, uniform in character.

Working Property—Good.

Water necessary to develop plasticity = 38.1 per cent.

Strength of unburned clay—Cross-breaking test. Modulus of rupture = 229.8 pounds per square inch.

Bonding strength with equal parts of standard sand. Modulus of rupture = 176 pounds per square inch.

Slaking test = 12 minutes.

Fineness test:

20-mesh sieve	No residue
60-mesh sieve	No residue
80-mesh sieve	No residue
120-mesh sieve	.01
200-mesh sieve	.01

Drying shrinkage, linear = 6.5.

Burning conduct:

	Color	Hardness	Total Shrinkage	Porosity
Cone 2	Grayish-white	Steel hard	11.2	26.7
Cone 5	Grayish-white	Steel hard	14.2	16.3
Cone 9	Grayish-white	Steel hard	14.4	12.7
Cone 12	Grayish-white	Steel hard	15.9	2.5

Fusion test: Deforms at cone 33.

This clay burns to a good color, has good strength in the unburned state, and is quite refractory. It is rather open burning at

cone nine and is a typical ball clay. It is suggested that it may be useful for the many purposes for which ball clay is used, and also in the manufacture of special refractories, chemical stoneware, terra cotta, face brick, abrasives, and saggers.

The ball clay is employed by insulator and porcelain manufacturers. Two hundred yards southwest of the pit this clay grades into a pale pink to white wad clay, finally merging into a fine, quartz sand, well stratified. This indicates that the transporting waters, at the time of deposition of these sediments, came from a southwesterly direction.

Upon closer examination of the claret discolorations already alluded to we find they have a nucleus of concretionary ironstone. Some of these are hollow and contain a limonitic clay pellet in their interior. It is said that the red color in the clay bleaches in the sunlight.

Occasional fossil-leaf impressions are found in the bedded clay. The whole clay deposit is traversed by several systems of joint planes, the most conspicuous of which has the following attitude: Strike: south 42° west; dip 28° NW.

The clay is carried by auto trucks and wagons to Hazel, Ky., five and one-half miles distant, to be loaded there for shipment. One hundred and twenty-five cars of clay a year are shipped from these mines.

Pit No. 11.—This pit is owned and operated by the same company. It is situated one-half mile south of Pit No. 9 on the east side of the hill. This pit was opened in September, 1917. About two acres of clay are available, or 22,500 tons.

Section.

Dark, earthy sand	2 feet
Gravel, poorly stratified, pebbles up to 1 inch diameter interbedded with red sand	12-25 feet
Local unconformity	
Sand, yellow, well-bedded, dips towards east	0-4 feet
Hard-pan	2 inches
Ball clay, upper half of stratum is white and pink; lower half is dark brown (thickness of each, 3½ feet)	7 feet
This stratum was sampled as "Light Ball No. 11" (upper part), and "Dark Ball No. 11" (lower part).	
Lignitic clay, pinches out towards northwest	5 feet
Clay, pale yellow, very plastic and free from grit	2 feet
Sand, yellow, merges into a brown, micaceous, sandy clay with depth	

The accompanying tests were made at the Ceramic Laboratory of the University of Illinois, under the direction of Prof. Cullen W. Parmelee.

Result of Tests.

Light Ball Mine No. 11.

Received from Cooley Ball & Sagger Clay Co.

Locality—Five miles west of Hazel, Ky.

Kind of Material—Light grey, plastic clay, somewhat stained.

Working Property—Good.

Water necessary to develop plasticity—41 per cent.

Strength of unburned clay—Cross-breaking test. Modulus of rupture = 167.3.

Bonding strength with equal parts of standard sand. Modulus of rupture = 61.4.

Slaking test—8 minutes.

Fineness test:

20 M.	No residue
60 M.	No residue
80 M.	No residue
120 M.	No residue
200 M.	0.09 white sand

Drying shrinkage, linear = 7.5 per cent.

Burning conduct:

	Color	Hardness	Shrinkage	Porosity
Cone 2	Grayish-white	Steel hard	11.4	28.9
Cone 5	Grayish-white	Steel hard	15.7	19.2
Cone 9	Grayish-white	Steel hard	16.3	11.1
Cone 12	Grayish-white	Steel hard	17.5	.86

Fusion test: Deforms at cone 33.

This clay burns to a good color, has good strength in the unburned state and is quite refractory. It is rather open burning at cone nine. It is suggested that it will be useful for the many purposes to which ball clay is put and also for the manufacture of special refractories, terra-cotta, chemical stoneware, face brick, abrasives and saggers.

Dark Ball Mine No. 11.

Received from Cooley Ball & Sagger Clay Co.

Locality—Five miles west of Hazel, Ky.

Kind of Material—Light cream-colored plastic clay, uniform in character, of medium hardness.

Working Property—Good, slightly sticky.

Water necessary to develop plasticity—41.8 per cent.

Strength of unburned clay—Cross breaking test. Modulus of rupture = 199 pounds per square inch.

Bonding strength with equal parts of standard sand. Modulus of rupture = 232 pounds.

Slaking test = 7 minutes.

Fineness test:

40 M.		No residue
20 M.		No residue
60 M.		Trace residue
80 M.		Trace residue
120 M.	(chiefly white sand)	.03
200 M.		.11

Drying shrinkage, linear = 6.3 per cent.

Burning conduct:

	Color	Hardness	Shrinkage	Porosity
Cone 2	Grayish-white	Steel hard	10.3	33.7
Cone 5	Grayish-white	Steel hard	14.1	18.5
Cone 9	Grayish-white	Steel hard	14.7	16.0
Cone 12	Grayish-white	Steel hard	16.6	4.0

Fusion test: Deforms at cone 32.

This clay burns to a good color and has good strength in the unburned state. It is rather open burning at cone nine, has good refractoriness and will be useful for the many purposes to which ball clay is put. It may be used in the manufacture of special refractories, chemical stoneware, terra cotta, face brick, abrasives and saggers.

Pit No. 10.—This pit is owned and operated by the same company and is 200 yards west, and across the hill, from Pit No. 11. It is probable that these two pits are being worked in opposite directions in the same clay stratum. The hill which separates the two pits is about sixty feet high. A well bored in the summit to a depth of fifty feet did not encounter the clay. Its log is as follows:

Log of Well.

Red, earthy sand	14 feet
Red sand and gravel with occasional clay pellets	34 feet

The clay mined at this pit is inferior in quality to that obtained in Pits No. 9 and 11. Altogether, 100 cars of clay have been shipped from this pit. Lignite fragments occur in the clay.

Section.

Red, clayey sand	4 feet
Red and yellow sands, thickening greatly towards north	4+ feet
Local unconformity.	
Hard pan (east end of pit)	1-2 inches

Ball clay, grey merging into pink at east end (sampled as "Grey Ball No. 10") ..... 4-5 feet
Sand, yellow and red .....

Result of Tests.

Sample No. —, Grey Ball Mine No. 10.

Received from Cooley Ball & Sagger Clay Co.

Locality—Five miles west of Hazel, Ky.

Kind of Material—Plastic clay, fairly uniform in character of a grey color, with slight stains.

Working Property—Good.

Water necessary to develop plasticity—35 per cent.

Strength of unburned clay—Cross-breaking test. Modulus of rupture = 225 pounds per square inch.

Bonding strength with equal parts of standard sand. Modulus of rupture = 164.6 pounds.

Slaking test—7 minutes.

Fineness test:

20 M.	No residue	
60 M.	No residue	
80 M.	No residue	
120 M.	(white sand)	.01
200 M.	(white sand)	.04

Drying shrinkage, linear = 5.7 per cent.

Burning conduct:

	Color	Hardness	Shrinkage	Porosity
Cone 2	Grayish-white	Steel hard	11.0	25.4
Cone 5	Grayish-white	Steel hard	12.6	10.4
Cone 9	Grayish-white	Steel hard	13.1	2.2
Cone 12	Grayish-white	Steel hard	14.0	.26

Fusion test: Deforms at cone 31.

This clay burns to a good color, has good strength in the unburned state. It has a good degree of vitrification at cone nine and is refractory. It may be used as a ball clay or in the manufacture of special refractories, chemical stoneware, terra cotta, face brick, abrasives and saggers.

Johnson and Porter's Wad Mine.—This pit is situated about one-quarter of a mile from Whitlock and is operated by the Johnson-Porter Clay Co., of Paris. Its area is about one acre and there are ten acres of clay available. Some sagger clay has been shipped from this pit and it is claimed that there is a two-foot bed of dark ball clay on the north side. At the time this pit was visited part of the

clay deposit was concealed by slump material. The following section was noted:

Section at Pit.

Red, clayey sand, yellow towards base	12-20 feet
Clay, white, plastic, sandy, especially on north side of pit, merging into pink locally; thickest at south end of pit	10-14 feet

The clay is carted to Whitlock for shipment.

Jackson or Porter's Pit.—This pit is owned and operated by the Johnson-Porter Clay Co., of Paris. It is situated five and one-half miles east of Paris near the Louisville & Nashville Railroad. It is about two acres in area and was not being worked at the time it was visited. The body of the clay underlies a low prominence, and the upper surface of the clay dips gently with the slope of the hill, as is so frequently the case. According to Mr. Walter C. Johnson there are ten acres of clay still available and the annual production has been 6,000 tons. Shortage of cars due to embargoes and scarcity of labor have hindered operations somewhat. The clay is carted to Porter's Switch on the Louisville & Nashville Railroad, where it is loaded for shipment.

The following section was noted:

Section at Jackson Pit.

Overburden—Yellow-brown and red sands, poorly bedded and case-hardened, containing thin beds of iron hard-pan	5-8 feet
Clay, brown to black, lignitic, massive, not much sand	0-10 inches
Clay, light grey and bluish grey, plastic when wet, only slightly sandy, known as "J-1 stone fracture." (Sample Tennessee No. 6)	4-6 feet
Bed of quartz sand, coarse, containing muscovite	½ inch
Clay, ball, very dark brown and lignitic in upper portions, merges into grey at depth of one foot. Contains little pockets of yellow limonitic sand in places. This bed pinches out between the overlying beds, known as "No. 1 Ball Clay, glass fracture." (Sample Tennessee No. 7)	1½-4 feet
Clay, cream color, no sand, not quite as good quality as overlying beds	2-6 feet

Result of Tests.

These tests were made at the Ceramic Laboratory of the University of Illinois, under the direction of Prof. Cullen W. Parmelee.

Sample—Tennessee No. 6.

Received from Wilbur A. Nelson, Tennessee Geological Survey.

Locality—Jackson Pit, five miles east of Paris, Tenn. (Upper White, "J-1 stone fracture.")

Kind of Material—Plastic clay. Light color, mottled with dark brown, red and yellow; some lumps are brown. It is medium hard.

Working Property—Good.

Water of plasticity = 33 per cent.

Bonding strength of a mixture of equal parts of standard sand. Modulus of rupture = 190.5 pounds per square inch.

Strength of the unburned clay—Cross-breaking test. Modulus of rupture = 179.2 pounds per square inch.

Slaking test = 12 minutes.

Fineness test:

20-mesh sieve	No residue
40-mesh sieve	No residue
60-mesh sieve	0.27%
80-mesh sieve	No residue
120-mesh sieve	0.42%
150-mesh sieve	0.09%
200-mesh sieve	0.24%

Drying shrinkage, linear, 7.5 per cent.

Burning conduct:

	Color	Hardness	Total Linear Shrinkage	Porosity
Cone 2	Cream	Steel hard	13.50%	20.0
Cone 5	Cream	Steel hard	13.60%	16.8
Cone 9	Gray	Steel hard	13.8 %	3.9
Cone 12	Light brown	Steel hard	14.0 %	1.1
Cone 13		Steel hard	13.7 %	3.6

Fusion test: Deforms at cone 31.

The color of this clay when burned at cone nine is rather dark, due probably to reducing conditions in the kiln. Vitrification at this temperature is good. The strength of the unburned clay is good. It is a ball clay type and will be found of value for such uses as ball clays are commonly put to, with a possibility of some service in the manufacture of refractories of certain sorts where a plastic refractory clay is needed.

Test on Sample No. 7.

Received from Tennessee Geological Survey.

Collected by Wilbur A. Nelson.

Locality—Jackson Pit, five miles east of Paris, Tenn. (Middle black, 4 feet thick.)

Kind of Material—A dark gray plastic clay mottled with red and brown. It is of a medium hardness.

Working Property—Good, slightly sticky.

Water necessary for plasticity = 33.7 per cent.

Strength of the unburned clay—Cross-breaking test. Modulus of rupture = 165 pounds per square inch.

Bonding strength of a mixture of equal parts of standard sand. Modulus of rupture = 225 pounds per square inch.

Slaking test = 10 minutes.

Fineness test:

40-mesh sieve		No residue
60-mesh sieve		No residue
80-mesh sieve		No residue
120-mesh sieve	(mica and sand)	0.4%
150-mesh sieve	(mica and sand)	0.4%
200-mesh sieve	(mica and sand)	0.5%

Drying shrinkage, linear, 8.1 per cent.

Burning conduct:

	Color	Hardness	Total Shrinkage	Porosity
Cone 2	Cream	Steel hard		17.9%
Cone 5		Steel hard	16.0	15.7%
Cone 9	Light tan	Steel hard	18.2	9.5%
Cone 12	Tan	Steel hard	18.0	3.6%
Cone 13		Steel hard	18.7	6.5%

Fusion test: Deforms at cone 30.

The color of this clay when burned at cone nine is rather dark for a ball clay, which possibly may be due to a slight reduction in the kiln. The strength of the unburned clay is good. Vitrification at cone nine is fairly good. It is a ball clay, is fairly refractory and may find some use as bond clay in special refractories; it may also be used for chemical stoneware, stoneware, abrasives, terra cotta, face brick and saggers.

Williams and Dalton Mines.—These two pits are situated close together, four miles east of McKenzie, and are owned and operated by the Johnson-Porter Clay Co., of Paris, Tenn. Mr. M. W. Younkin of McKenzie is manager. The pits are connected by narrow gauge track with the Johnson-Porter spur from McKenzie. The clay body here is large and is overlain by a heavy overburden of typical Lagrange sand, which is moved by a contractor by means of steam shovel and mule teams. The pits are large, each one covering several acres. The clay is shipped to potteries, porcelain, enamel and electric ware manufacturers. Some is also used by glass-pot makers.

Section at Williams Pit.

Sand, yellow, brown and red, with clay pellets and ironstone concretions	36-40 feet
Clay (Tenn. Ball No. 10), white, streaked with pink, exceedingly plastic. Used for porcelain. (No. 27 S.)	5 feet
Clay, lignitic	3 inches
Clay (Tenn. Ball No. 9), dark grey to brown, very plastic and free from grit. This is the best clay in the pit, and is used by glass-pot makers. Grades into a light brown clay known as Tenn. Ball No. 11. Ball No. 9 sampled. (No. 28 S.)	4 feet
Clay, black and lignitic	Depth not tested

Result of Tests.

Tennessee Ball, No. 9.—A preliminary test only was made on this clay, complete tests having been made only in cases where the clay seemed promising as a *highly refractory bond clay* such as is used in the manufacture of glass-pots and crucibles (in demand by our government as a war mineral). The Survey hopes to make additional tests on this sample.

Sample No. 27 S—Upper stratum.

This test was made at the Ceramic Laboratory of the University of Illinois, under the direction of Prof. Cullen W. Parmelee.

Received from Tennessee Geological Survey.

Locality—Four miles from McKenzie, Tenn. Williams Mine, Johnson-Porter Clay Co.

Kind of Material—Plastic clay.

Color—Light cream with pinkish tinge. Uniform in appearance.

Hardness—Medium.

Working Property—Very sticky.

Water of plasticity = 35.5 per cent.

Strength of the unburned clay—Cross-breaking test. Modulus of rupture = 240 pounds per square inch.

Bonding strength = modulus of rupture, 138.9 pounds per square inch.

Slaking test = 12 minutes.

Fineness test:

20-mesh sieve	No residue	
40-mesh sieve	No residue	
60-mesh sieve	No residue	
80-mesh sieve	No residue	
120-mesh sieve	(residue white sand)	0.08%
200-mesh sieve	(residue white sand)	0.67%

Drying shrinkage, linear, 8.82 per cent.

Drying conduct—poor.

Burning conduct:	Hardness	Color	Porosity	Total Shrinkage
Cone 2	Steel hard	Dark tan	0.78	6.0%
Cone 5	Steel hard			16.2%
Cone 9	Steel hard	Light brown	1.8	13.3%
Cone 12	Steel hard	Light brown	6.2	11.7%
Cone 13	Steel hard	Light brown	15.0	13.0%

Fusion test: Deforms at cones 32-33.

The color of this clay when burned is dark and hence will not rank with the best ball clays. It is strong and is quite refractory and will serve for purposes where a plastic refractory clay is required as a bond clay. It may be used in the manufacture of chemical stoneware, stoneware, face brick and saggers, and possibly in the manufacture of abrasives. This clay will have to be burned carefully because of the apparent tendency to overburn at cone thirteen.

Tests on Tennessee Ball Clay No. 11.

This test was made at the Ceramic Laboratory of the University of Illinois, under the direction of Prof. Cullen W. Parmelee.

Received from Wilbur A. Nelson, Tennessee Geological Survey.

Locality—Williams Pit, Johnson-Porter Clay Co., McKenzie, Tenn.

Kind of Material—Plastic clay, a mixture of cream-colored and brownish-colored material, the latter predominating. It is moderately hard.

Working Property—Good, sticky.

Water of plasticity = 42.5 per cent.

Strength of the unburned clay—Cross-breaking test. Modulus of rupture = 95.3 pounds per square inch.

Bonding strength with equal parts of standard sand. Modulus of rupture = 118.6 pounds per square inch.

Slaking test = 9 minutes.

Fineness test:

20-mesh sieve	No residue
40-mesh sieve	No residue
60-mesh sieve	No residue
80-mesh sieve	No residue
120-mesh sieve	Trace
150-mesh sieve	Trace
200-mesh sieve	Trace

Drying shrinkage, linear, 5.75 per cent.

Burning conduct:	Color	Hardness	Total Shrinkage	Porosity
Cone 2	White	Steel hard	21.5	21.15%
Cone 5	White	Steel hard	16.3	19.6%
Cone 9	Grey-white	Steel hard	17.2	7.7%
Cone 12	Grey	Steel hard	17.8	2.2%
Cone 13		Steel hard	17.5	3.4%

Fusion test: Deformed at cone 32-33.

The strength of this clay appears to be rather low. The color is very good and it is fairly well vitrified at cone nine. It is a clay which is fairly representative of the ball clay type and will find use as such, also will be of service for the manufacture of sanitary ware, chemical stoneware, stoneware, face brick, terra cotta and saggers. Its rather high fusion point is likely to make it of service in the manufacture of certain types of refractories, where a plastic clay of good strength is desired.

Section at Dalton Mine.

Lafayette—Sand and clay, red and case-hardened ..... 10 feet

Lagrange—Sand, clayey, brown, containing clay pellets and ironstone concretions and layers, also a clay breccia towards the base ..... 12 feet

Clay, white, sandy in places and not so plastic as Williams Mine clays, but has higher specific gravity. The ball clay is intimately intergrown with sagger and has to be separated by hand. The ball clay is used by enamelware makers on account of its vitrification point. It was sampled as No. 29 S. The saggar clay is known as XX Sagger and was sampled as No. 30 S. Thickness of whole stratum ..... 12 feet

Tests.

These tests were made at the Ceramic Laboratory of the University of Illinois, under the direction of Prof. Cullen W. Parmelee.

Sample No. 29 S.—This clay is not deformed at cone twenty-seven, slakes in thirteen minutes and burns white. Transverse test—184.3 pounds per square inch.

Sample No. 30 S.—This clay is not deformed at cone twenty-eight, slakes in thirteen minutes, and the transverse test showed a modulus of rupture of ninety-six pounds per square inch.

A preliminary test only was made on these clays, complete tests having been made only in cases where the clay seemed promising as a *highly refractory bond clay*, such as is used in the manufacture of glass-pots and crucibles (in demand by our government as a war

mineral). The Survey hopes to make additional tests upon these samples.

Diggs' Pit.—This pit is the property of A. P. Diggs and is operated only intermittently. It is situated two and a half miles west of Paris on the New Boston Road. The clay has been removed over a circular area of about an acre and has been sold as ball clay. Borings show it to underlie six acres and outcrops may be seen along a small gully for a distance of 200 feet towards the west. Several springs emerge from the upper surface of the clay deposit. Drainage is good, being accomplished by a gully to the west. The clay underlies a low prominence and is easily removed.

The following section was noted:

Section at Diggs Pit.

Sand, pale brown, containing ironstone concretions and intraformational clay and lignite fragments. Contains thin beds of white and pink clay near base. The sand is colored orange and red and is case-hardened around the ironstone concretions	5-15 feet
Unconformity	
Lignitic clay, with well-preserved pieces of wood, resembling hickory. Some of the fragments are two feet long. Lignite pinches out to the west	1-2 feet
Clay, grey, not very plastic, contains fossil leaf impressions. Pinches out towards the west. Sample No. 59 S	5 feet
Clay, dark greyish green, non-plastic and contains leaf impressions. Sample No. 56 S	1½ feet
Clay, pink, similar to above, becoming sandier with depth and bedded. This bed may thicken towards the east and should be prospected	5 feet

Result of Tests.

No. 56 S.—This clay is deformed at cone thirty-two (very refractory), is slow in slaking and has a high modulus of rupture, 262 pounds per square inch, as shown by the transverse strength test.

No. 59 S.—This clay is deformed at cone thirty-one (refractory), and slakes in seven and one-half minutes.

A preliminary test only was made on these clays, complete tests having been made only in cases where the clay seemed promising as a *highly refractory bond clay* such as is used in the manufacture of glass-pots and crucibles (in demand by our government as a war mineral). The Survey hopes to make additional tests upon these samples.

S. and J. Jackson's Pit.—This is a small pit situated one-quarter mile east of India. The clay is a low grade sagger underlain by a thin bed of ball clay. Sagger clay is mined and carted to Porter's Switch on the Louisville & Nashville Railroad, three and one-half miles distant.

Section.

Sand, brown, with cherty gravel	5 feet
Clay, grey, micaceous	8 feet
Clay, chocolate brown. very plastic, contains occasional specks of limonite (sample No. 41 S)	1-3 feet
Clay, grey-blue sagger	2½ feet
Sand, white	

Result of Tests.

This test was made at the Ceramic Laboratory, University of Illinois, under the direction of Prof. Cullen W. Parmelee.

Sample No. 41-S.

Received from Tennessee Geological Survey.

Collected by R. A. S.

Locality—S. J. Jackson's Pit, one-fourth mile east of India. Lower stratum.

Kind of Material—Borings; a dark gray-colored clay, stained slightly with yellow. It contains some mica.

Working Property—Good, slightly sticky.

Water necessary for plasticity = 39.5 per cent.

Strength of unburned clay—Cross-breaking test. Modulus of rupture = 262.3 pounds per square inch.

Bonding strength with equal parts of standard sand—Cross-breaking test. Modulus of rupture = 142 pounds per square inch.

Slaking test = 20 minutes.

Fineness test:

20-mesh sieve, residue	0.27%
40-mesh sieve, residue	None
60-mesh sieve, sand residue	0.08%
80-mesh sieve, residue	0.01%
120-mesh sieve, residue sand and mica	0.07%
200-mesh sieve, residue sand and mica	0.18%

Drying shrinkage, linear = 6.25 per cent.

Burning conduct:	Color	Hardness	Total Shrinkage	Porosity
Cone 2	White	Steel hard	11.80%	34.7%
Cone 5	Light grey	Steel hard	17.1%	10.8%
Cone 9	Light grey	Steel hard	17.2%	13.4%
Cone 12	Light grey	Steel hard	18.8%	1.7%

Fusion test: Deformed at cones 32-33.

This clay burns to a good color at cone nine and it has good strength in the unburned state, but it is rather more open burning than the typical ball clay; however, it will find some use for such purposes as these clays serve. It is suitable for the manufacture of sanitary ware, chemical stoneware, stoneware, face brick, terra cotta, saggers and abrasives. It will probably be useful in the manufacture of refractories requiring a strong plastic clay.

The Mill Pit.—This pit was formerly worked by the Mandel interests but has been abandoned. It is now controlled by H. C. Spinks Clay Co. and W. Allison. It is situated three and a half miles west of Puryear and reached by a very poor road. The old pit is about one acre in area and is well drained by gullies. The clay is said to underlie eight to possibly twenty-five acres. A spring emerges from the surface of the clay.

Section.

Lafayette—Brick red, massive, case-hardened sands with cherty gravel	4 feet
Lagrange—Sand, brown and yellow, with thin beds of white; contains ironstone concretions near base and is strongly cross-bedded	10 feet
Clay, putty color, very plastic, especially the top portion, occasional pale yellow and pink discoloration. (Sample No. 58 S.)	5 feet
Clay, same properties, only color brown. Is said to merge into lignite towards east	1 foot
Clay, putty grey, not so plastic, gets sandier with depth	6 feet
Sand, white (iron has been leached out by descending waters)	

Result of Tests.

No. 58 S.—This clay is deformed at cone twenty-eight and slakes in eight minutes.

A preliminary test only was made, complete tests having been made only on those clays which seemed promising as *highly refractory bond clays*, such as are used in the manufacture of glass-pots and crucibles (in demand by our government as a war mineral). The Survey hopes to make further tests.

Sparks' Pit.—This pit is about five miles west of Henry, and directly north of McKenzie, on the road to Como. It is leased by the Chrisman-Reynolds Clay Co., of Henry.

The pit is located on the east side of the road on a steeply sloping hillside, and has been dug back into the hill about 100 feet, with a width of fifty feet. At present the pit is filled with water, which could be siphoned off. The overburden has been dumped to interfere with

the natural drainage into the nearby ravine. The following section was made by Wilbur A. Nelson, State Geologist:

Section of C. Sparks' Pit.

Lafayette—Sand, light orange, darker at base and case-hardened, with a sprinkling of gravel ..... 5-15 feet

Lagrange—Clay, white with pink streaks, flinty fracture with slight incrustation of a white crystalline substance along the cracks. Clay turns to dark brown at 12 feet and then back to white at base 15 feet

This fifteen-foot stratum of clay was sampled and tested as No. 4.

Result of Test.

This test was made at the Ceramic Laboratory of the University of Illinois, under the direction of Prof. Cullen W. Parmelee.

Sample Tennessee No. 4, second sampling.

Received from Wilbur A. Nelson, Tennessee Geological Survey.

Locality—Sparks Pit, near McKenzie, Henry County.

Kind of Material—Plastic clay of a cream color with some pinkish spots. It is of medium hardness.

Working Property—Good.

Water of plasticity, 31.8 per cent.

Strength of unburned clay—Cross-breaking test. Modulus of rupture = 101.2 pounds per square inch.

Bonding strength of a mixture of equal parts of standard sand. Modulus of rupture = 108 pounds per square inch.

Slaking test = 5 minutes.

Fineness test:

40-mesh sieve	No residue
60-mesh sieve	No residue
80-mesh sieve	No residue
120-mesh sieve	Trace white sand
150-mesh sieve	Trace white sand
200-mesh sieve	Trace white sand

Drying shrinkage, linear, 5.2 per cent.

Burning conduct:

	Color	Hardness	Total Shrinkage	Porosity
Cone 2	Cream	Steel hard	11.2	2.1
Cone 5	Tan	Steel hard	12.1	21.0
Cone 9	Gray	Steel hard	14.3	1.6
Cone 12	Gray	Steel hard	14.0	1.5
Cone 13		Steel hard	11.9	4.5

Fusion test: Deformed at cone 28.

The color of the burned sample is not quite satisfactory, possibly due to reducing conditions in the kiln, and it seems doubtful that

the clay will be available for use in the manufacture of white wares, because of the evidently high iron content. The strength of the clay is fair. It fuses at too low a temperature to permit its use in the manufacture of refractories which are to withstand high temperatures. It is likely that this clay will be more serviceable in the manufacture of chemical stoneware, stoneware, face brick and terra cotta.

Breedlove Pit.—This pit is leased by the Scates-Reynolds Clay Co., of Henry, and is situated about one and a fourth miles southwest of Henry Station. It is circular in shape and about 150 feet in diameter. (See Fig. 11.) The overburden, which ranges from ten to eighteen

Photo by H. Ries.

FIGURE 11—Breedlove Pit, near Henry, Scates-Reynolds Clay Co.

feet in thickness, is dumped a short distance away down a hillside. The clay underlies an area of about ten acres and would amount to 290,385 tons (using twelve feet as the average thickness). Fifty carloads of clay were mined and shipped from here in June, 1918.

Section.

Sandy clay, brown and white	5 feet
Sand, yellow and red-brown, cross-bedded with ironstone concretions and crusts near base	12 feet
Clay,* white, plastic sagger	5 feet
Clay,* very tough, white and plastic	3½ feet
Clay,* white sagger, merges into a white wad clay with pink streaks towards south	5 feet
Ironstone concretions overlying a short, white wad clay	6 feet
Sand, coarse and grey	

*(This bed was sampled as No. 5.)

Result of Test.

This test was made at the Ceramic Laboratory of the University of Illinois, under the direction of Prof. Cullen W. Parmelee.

Sample No. 5. Our No. 115.

Received from Tennessee Geological Survey.

Collected by Wilbur A. Nelson.

Locality—Breedlove Pit, near McKenzie.

Kind of Material—Light cream-colored plastic clay, uniform in character and moderately hard.

Working property—Good.

Water necessary for plasticity = 27.2 per cent of weight of dry clay.

Strength of unburned clay—Cross-breaking test. Modulus of rupture = 69.3 pounds per square inch.

Bonding strength of a mixture of equal parts sand. Modulus of rupture = 112 pounds per square inch.

Slaking test = 8 minutes.

Fineness test:

20-mesh sieve	No residue
40-mesh sieve	No residue
60-mesh sieve	No residue
80-mesh sieve	No residue
120-mesh sieve	No residue
150-mesh sieve	No residue
200-mesh sieve	No residue

Drying shrinkage, linear, 5.6 per cent.

Burning conduct:

	Color	Hardness	Total Shrinkage	Porosity
Cone 2	Light cream	Steel hard		24.8
Cone 5	Light cream	Steel hard	10.3	25.3
Cone 9	Light cream	Steel hard	13.2	8.8
Cone 12	Light grey		14.0	4.8
Cone 13			10.	5.5

Fusion test: Deforms at cone 28.

This clay has a good color when burned. It shows a fair vitrification at cone nine. The strength of the unburned clay is low. It is not sufficiently refractory to be considered as a plastic refractory bond clay. It is likely to be of service in the manufacture of sanitary ware, chemical stoneware, stoneware, face brick and saggers.

Bradlee Pit.—This is a small pit, about thirty feet across, on the land of Thomas Bradlee about three miles southeast of Puryear. It is leased by H. I. Nealy and M. T. Sanders. The clay is a moderately plastic sagger clay and underlies four acres, amounting to

77,000 tons in the bank. It is carted three miles to Puryear for shipment.

Section.

Gravel	3-5 feet
Clay, brown, moderately plastic, stratified and somewhat sandy, contains fossil leaf impressions near base. Sample No. 43 S.	8 feet

A thin bed of sand in the pit shows faulting on a small scale. The displacement is about ten inches, the down-throw block being towards the east. Slight folding or crenulation has also affected these beds.

Result of Tests.

This test was made at the Ceramic Laboratory of the University of Illinois, under the direction of Prof. Cullen W. Parmelee.

Sample No. 43 S.

Received from Tennessee Geological Survey.

Collected by R. A. S.

Locality—Thomas Bradlee farm, leased to M. T. Sanders and H. C. Nealy, three miles southeast of Puryear.

Kind of Material—A clay of a dark gray color with occasional brown stains. It is of uniform texture and contains a small amount of carbonaceous material in the form of fossil leaves. A small amount of mica is present.

Working property—Good.

Water necessary to develop plasticity = 37.3 per cent.

Strength of unburned clay—Cross-breaking test. Modulus of rupture = 182.7 pounds per square inch.

Bonding strength with equal parts of standard sand, cross-breaking test. Modulus of rupture = 83.2 pounds per square inch.

Slaking test = 20½ minutes.

Fineness test:

20-mesh sieve	No residue
40-mesh sieve	No residue
60-mesh sieve	No residue
80-mesh sieve	No residue
120-mesh sieve	0.06% residue
200-mesh sieve	0.14% residue

Drying shrinkage, linear = 5.7%.

Burning conduct:

	Color	Hardness	Total Shrinkage	Porosity
Cone 2	White	Steel hard	10.0	38.2
Cone 5	Greyish-white	Steel hard	15.7	15.4
Cone 9	Greyish-white	Steel hard	13.2	10.9
Cone 12	Greyish-white	Steel hard	17.4	2.1

Fusion test: Deforms at cone 31.

This clay burns to a good color at cone nine. Its strength when unburned is good; it will find use as a ball clay. It has rather high fusion test and probably will serve where a refractory plastic clay is required, in the manufacture of certain wares. It will serve also in the manufacture of sanitary wares, chemical stoneware, stoneware, saggers and abrasives.

Abandoned Pits in Henry County.

Mandle Clay Mining Co., Pits No. 9, No. 7 and Monroe Pit.
Johnson-Porter Clay Co., Pits No. 9 and No. 11.
"Old Currier Pottery Pit."

HENRY COUNTY PROSPECTS.

Cooley Ball and Sagger Clay Co. Prospect.—Clay is exposed in a gully adjacent to a hill, about 300 yards east of Pit No. 9 of the same company. There are about twelve feet of good clay in a stratum which underlies a fifty-foot hill. Although the overburden increases to forty feet at the summit the clay could be worked around the hill. A creek just below the clay bed would easily drain a pit opened here. Timber is abundant.

Section.

Sand	0-40 feet
Clay, sandy, white	4 feet
Clay, brown, plastic, no grit; contains leaf impressions. (Sample No. 50 S)	8 feet
Clay, similar in character, slightly sandy	Several inches
Clay, pale yellowish brown, very plastic and free from impurities	3½ feet

Result of Test.

This test was made at the Ceramic Laboratory of the University of Illinois, under the direction of Prof. Cullen W. Parmelee.

Sample No. 50 S (borings).

Received from Tennessee Geological Survey.

Collected by R. A. S.

Locality—From gully exposure 300 yards east of Pit No. 9 of the Cooley Ball & Sagger Clay Co. property, five and one-half miles west of Hazel, Ky.

Kind of Material—A dark grey clay with brown mottling. A few mica particles are present.

Working property—Good.

Water necessary to develop plasticity = 37 per cent.

Strength of unburned clay—Cross-breaking test. Modulus of rupture = 231.9 pounds per square inch.

Bonding strength with equal parts of standard sand—Cross-breaking test. Modulus of rupture = 118 pounds per square inch.

Slaking test = 20 minutes.

Fineness test:

20-mesh sieve	Trace of residue
40-mesh sieve	No residue
60-mesh sieve	Trace of residue
80-mesh sieve	No residue
120-mesh sieve	0.02%
200-mesh sieve	Trace of residue

Drying shrinkage, linear = 6.1 per cent.

Burning conduct:

	Color	Hardness	Total Shrinkage	Porosity
Cone 2	White	Not steel hard	9.75	37.1
Cone 5	Light cream	Steel hard	14.2	31.2
Cone 9	Light grey	Steel hard	15.3	7.8
Cone 12	Light grey	Steel hard	16.5	1.0

Fusion test: Deforms at cone 31.

This clay burns to a good color. It has a fair degree of vitrification at cone nine. The strength of the unburned clay is good and it would seem that this clay would find use as a ball clay. Because of its rather high fusion test will probably give service as a ball clay in the manufacture of certain refractories. It may be used for the manufacture of sanitary ware, chemical stoneware, face brick and saggers.

S. J. Moore's Prospect.—This prospect is on the farm of E. Stevens, one mile northwest of Puryear on Route 3. The clay outcrops in front of his house on the road. Although there are no other exposures in sight, the clay underlies several acres of cultivated land as has been shown by numerous test holes bored by Mr. Stevens. A strong spring emerges within twenty feet of the outcrop. The overburden ranges between zero and fifteen feet and consists of brown, earthy, loose sand. An auger hole bored at the outcrop shows the following section:

Clay, white and rusty, sandy	8½ feet
Clay, pale brown to putty grey, slightly sandy. (Sample No. 57 S)	4 feet
Clay, same only sandier	Depth not ascertained

The tests show that this clay is not deformed at cone twenty-eight and slakes in seven minutes.

A preliminary test only was made on this clay, complete tests having been made only in cases where the clay seemed promising

as a *highly refractory bond clay* such as is used in the manufacture of glass-pots and crucibles (in demand by our government as a war mineral). The Survey hopes to make additional tests on this sample.

C. M. Kennerly Prospect.—This deposit is situated four miles east of Puryear. The clay outcrops in several gullies but the quantity and quality do not warrant further investigation. The clay is white and sandy and nowhere over two feet thick. Prospecting may reveal the presence of larger clay bodies.

S. and J. Jackson Prospect.—This prospect is situated about 500 feet south of their clay pit, near India. The clay outcrops in a slight depression in a pasture. An auger hole revealed the following section:

Brown sand and siliceous gravel, with pebbles up to 2½ inches diameter	5-10 feet
Clay, chocolate color, with occasional pockets of rust and mica, somewhat sandy (Sample No. 42 S)	16 feet

Further prospecting holes should be bored to ascertain the quality of the clay in different locations. The sample was not tested.

**Cottage Grove.*—Just north of this town is a four-foot exposure of ball clay, which occurs in the bottom of a gully on the land of Mr. E. Brizentine. It has an overburden of fifteen or twenty feet.

Result of Test.

This clay is somewhat sticky when wet. Its natural color is grey, which turns very dark on adding water, remaining so until dry, when it becomes dark cream. About two-thirds of the discs and briquettes warped somewhat on drying but not badly. Five of the tensile strength briquettes out of twenty-two broke in the head and were not taken into account.

		Per cent
Water of plasticity of discs and briquettes		25.5
Water of plasticity of tensile strength briquettes		24.5
Tensile strength in pounds per square inch		115.6
Average per cent variation tensile strength briquettes		10.5
Drying shrinkage		5.3
Burning shrinkage;	cone 4	5.0
	cone 6	9.5
	cone 8	7.5
Porosity of burned clay;	cone 4	22.5

*Resources of Tennnessee, Vol. 2, No. 11.

	cone 6	7.4
	cone 8	10.3
Color of burned pieces;	cone 4	(Cream)
	cone 6	(Dark cream)
	cone 8	(Dark cream)

The chief objection to this clay is its variability. Its character changes in some cases within a horizontal distance of fifteen or twenty feet, with a strong tendency towards sandy clay. The color of the burned clay is too dark for standard ball clay.

The Church and Mill Property.—This prospect is in the rear of the blacksmith's shop, on the outskirts of Cottage Grove. A large gully reveals the presence of clay for a horizontal distance of several hundred feet. Probably this deposit is simply another phase of the large clay body which underlies the whole town and outcrops on the Brizentine land to the north.

Auger Hole Section.

Pale brown, clayey sand	5-10 feet
Lignitic clay	2-3 feet
Clay, dark greenish grey, with leaf impressions. (Sample No. 51)	6 feet
Sand, white	½ inch
Clay, grey, becoming yellow and sandy	3½ feet
Clay, brick red	2 inches
Sand, white	

Result of Test.

Sample No. 51 S was deformed at cone twenty-eight and slaked in four minutes. Hence it is not a very refractory clay.

G. C. Dolan's Prospect.—This clay outcrops in a number of large gullies, over an area of ten acres, on the farm of G. C. Dolan, five miles southeast of Mansfield and two miles over a poor road to the Nashville, Chattanooga & St. Louis Railway. The overburden consists of orange, red and yellow sands, case-hardened and containing beds of gravel, with pebbles up to one-half inch diameter. The sand grains are white, transparent quartz, coated with varicolored iron oxides. Ironstone concretions are abundant. The thickness of the overburden varies from six to twenty feet with an average of ten. The clay surface dips with the slope of the hill. A thin bed of ironstone rests immediately above it.

Auger Hole Section.

Hard-pan	1-3 inches
Clay, white and plastic	4 feet
Clay, yellowish and pink	1 foot

Clay, chocolate brown, occasional yellow streaks, plastic with little sand. (Sample No. 44 S)	10 feet
Clay, grey and sandy	4 feet
Sand, clayey and grey	

Result of Tests.

A preliminary test only was made on this clay, complete tests having been made only on those clays which seemed promising as *highly refractory bond clays*, such as are used in the manufacture of glass-pots and crucibles (in demand by our government as a war mineral). The Survey hopes to make further tests on this sample.

This clay was not deformed at cone twenty-eight and slaked in ten minutes. Transverse test — modulus of rupture = 163 pounds per square inch (strong enough for ball clay).

M. H. R. Wright's Prospect.—This is situated on the Hico and Shilo Church Road, just east of Wright's Mill, in the fourth district. The clay is exposed in the roadbed and nowhere else. The overburden is light and should not exceed ten feet. The clay is chocolate brown, moderately plastic, and slightly sandy. It weathers white. An auger hole was bored to a depth of twelve feet without passing through the clay. Sample collected—No. 20 S.

The tests show that this clay burns to a cream color, slakes in seven minutes and is not deformed at cone twenty-eight.

Only a preliminary test was made, complete tests having been made only on *highly refractory bond clays*, such as are used in making glass-pots and crucibles. The Survey hopes to make additional tests on this clay.

C. W. Fulgham and J. W. Tucker's Prospect.—This deposit is situated four miles northwest of McKenzie and two miles northeast of the Nashville, Chattanooga & St. Louis Railway. The clay deposit is very large and underlies at least six acres and is fifteen to twenty-five feet in thickness, which would give a minimum of 260,000 tons in the bank. It underlies a hill about forty-five feet high on whose slopes it outcrops in numerous gullies. The clay weathers white, but is dark brown when fresh. Many prospecting holes have been bored showing that the thickness persists over a large area. An auger hole bored in the presence of the writer gave the following section:

Auger Hole Section

Clay, grey, impure and sandy	1½ feet
Clay, dark brown, moderately plastic and free from grit. (Sample No. 31 S)	15 feet
Clay, similar in character but somewhat sandy	3½ feet

The overburden varies from zero to twelve feet with an average of eight feet, and would be easy to remove as there is lower land on all sides where it could be dumped. There is a wooded slope towards the north under which the same clay is said to exist.

Result of Test.

This test was made at the Ceramic Laboratory of the University of Illinois under the direction of Prof. Cullen W. Parmelee.

Sample No. 31 S.

Received from Tennessee Geological Survey.

Collected by R. A. S.

Locality—C. W. Fulgham and J. W. Tucker's property, four miles northwest of McKenzie, two miles to N., C. & St. L. Ry.

Kind of Material—A dark grey-colored clay of fairly uniform character. It appears to be slightly sandy.

Working property—Good, slightly sticky.

Water necessary to develop plasticity = 35.7 per cent.

Strength of unburned clay—Cross-breaking test. Modulus of rupture = 878 pounds per square inch.

Bonding strength with equal parts of standard sand. Cross-breaking test. Modulus of rupture = 345 pounds per square inch.

Slaking test = 120 minutes.

Fineness test:

20-mesh sieve	No residue
40-mesh sieve	No residue
60-mesh sieve	0.03% sand
80-mesh sieve	0.04% sand
120-mesh sieve	0.17% sand, mica
200-mesh sieve	0.11% sand, mica

Drying shrinkage, linear = 7.7 per cent.

Burning conduct:

	Color	Hardness	Total Shrinkage	Porosity
Cone 2	Cream	Steel hard	10.5%	3.8 %
Cone 5	Grey	Steel hard	12.7%	1.19%
Cone 9	Grey	Steel hard	11.6%	1.43%
Cone 12	Grey	Steel hard	12.2%	2.1 %

Oxidation conduct = slow.

Fusion test: Deforms at cone 29.

This clay burns to a fair color at cone nine. It is well vitrified at cone five and has a very high strength in the unburned state. It is probably not quite as white as may be desired for a ball clay. In view of its rather high fusion test and its high strength, it seems probable that this will be of value in the manufacture of crucibles and similar wares. It may be used in the manufacture of chemical stoneware, stoneware, terra cotta, face brick, saggers and abrasives.

J. D. Lee's Prospect.—This clay outcrops in a spring hole on Mr. Lee's farm four miles north of Henry, which is the nearest railway town. The clay is exposed at only one point but appears to underlie a wooded hill of several acres area. The clay seems to be on the edge of a clay deposit and hence the sample taken may not be altogether representative, but it would be necessary to penetrate at least ten feet of overburden to procure a sample elsewhere. The following section was obtained by means of an auger hole:

Red and brown sand	10 feet
Clay, pink and plastic, only slightly sandy. (Sample No. 37 S.)	3 feet
Sand, pink	

Result of Test.

This clay was deformed at cone thirty (high) and slaked in nine minutes.

A preliminary test only was made on this clay, complete tests having been made only in cases where the clay seemed promising as a *highly refractory bond clay,* such as is used in the manufacture of glass-pots and crucibles (in demand by our government as a war mineral). The Survey hopes to make additional tests upon this sample.

John E. Edwards' Prospect.—This promising looking clay stratum outcrops on the Paris-Como Road, about three miles west of Paris. Only the top of the clay is exposed in the road ditch, over a distance of 252 feet. The body of the clay appears to dip gently towards the east and to have its maximum extension towards the south under a hill. Auger holes bored by Mr. Edwards showed the clay to be twelve feet thick at the eastern extremity of the outcrop and six feet thick at the western end. The overburden is twenty-seven feet thick. The following is a complete section:

Clayey sand, pale brown	6 feet
Sand, red, massive with thin ironstone strata	20 feet
Sand, white, with bright yellow and red stains in places	1 foot

Clay, white, with pink blotches, very plastic and free from grit. (Sample No. 48 S.)	4½ feet
Clay, white, somewhat less plastic. (Sample No. 49 S.)	6½ feet
Clay, white, sandy	

Result of Tests.

A preliminary test only was made on these clays, complete tests having been made only in cases where the clay seemed promising as a *highly refractory bond clay*, such as is used in the manufacture of glass-pots and crucibles (in demand by our government as a war mineral). The Survey hopes to make additional tests upon these samples.

No. 48 S.—This clay is not deformed at cone twenty-eight and slaked in six and one-half minutes.

No. 49 S.—This clay is deformed at cone thirty (high) and slakes in seven minutes. The transverse test shows a modulus of rupture of 154 pounds per square inch. (Ball clays generally have a strength of 150 pounds or better.)

Railway Exposure Near Routon.—A clay lens outcrops in a railway cut on the Louisville & Nashville Railroad three and a half miles south of Paris. It is under a low hill and its upper surface dips with the topography, the clay being thickest under the summit. This is a very common phenomenon in these clay beds. The clay is folded* locally into small anticlinal folds whose limbs dip 30° north. It is also jointed, the joint planes having the attitude—Dip 90°, strike S 60° E. The clay outcrops over a horizontal distance of 280 feet along the track. It was not sampled.

Section.

Sand, brown and red, case-hardened, containing small ironstone concretions	0-15 feet
Local unconformity.	
Clay, white and pink, sandy, well stratified with many well-preserved fossil leaf impressions	15 feet

Prospecting holes may reveal the presence of better grades of clay underneath.

SECTIONS IN HENRY COUNTY.

Section in gully six miles north of Paris on road to Conyersville.

Lafayette—Brick red, massive sand	8 feet
Coarse, siliceous gravel with pebbles up to two inches in diameter	4 feet

*The inclination of these beds may be caused by slumping.

Lagrange—Sand, pale yellow, orange and red, cross-bedded. Interstratified with grey and pinkish, micaceous clays and thick beds of ironstone. Contains clay pellets..... 35 feet

Section in gully, three and a half miles west of Paris on Como Road.

Columbia—Brown, clayey sand ..... 3 feet
Lafayette—Sand, brick-red, massive and case-hardened..... 2-10 feet
Unconformity.
Lagrange—Well-stratified, thin beds of orange sands, alternating with white to pink clay. The clay resists erosion better than the sand and projects in shelf fashion. This formation is rich in ironstone concretions and layers ..... 10-12 feet
Strongly cross-bedded, white, cream and orange colored sands with clay beds towards the base..... 5-8 feet

WEAKLEY COUNTY PROSPECTS.

F. H. Skates Prospect.—This clay outcrops in a cut on the Nashville, Chattanooga & St. Louis Railway, two and a half miles northwest of McKenzie. It was thoroughly tested and found to exist in too small quantity to warrant analysis. An auger hole showed the following section:

Sand, pale brown ..... 12 feet
Ball clay, grey ..... 3 feet
Sand ..... 1 inch
Ball clay, rose ..... 1 foot
Sand ..... ¼ inch
Ball clay, rose ..... 9 inches
Sand, yellow ..... 1 inch
Sand, grey.

Another auger hole only forty feet to the east, five feet deep, showed no clay. Another, thirty feet to the west, showed one and a half feet of ball clay underlain by sand. Mr. John Gardner, former owner, says he bored a hole on the summit of the hill, one hundred yards east of the railway, which showed twenty-two feet of sand underlain by eight feet of good clay. Another hole fifty yards from the track showed no clay at all. From the foregoing it would appear that the deposit, which outcrops on the track, is small and of no consequence but that there is a possibility of finding a separate clay lens one hundred yards back from the track towards the northeast.

William R. Bobo Prospect.—This is a large clay deposit which underlies the hill on which Mr. Bobo's residence is situated, one and

a half miles northeast of Christmasville. The clay outcrops are very white and chalky. There is apparently a large quantity of it available, for it outcrops one hundred yards along the road and a well near Mr. Bilbo's house encountered a thickness of twenty-two feet of clay at a depth of ten feet. The clay is in the Lagrange formation of Eocene age. The nearest railway is five miles distant.

Auger Hole Section.

Overburden, loose sand	10 feet
Clay, white, plastic (Sample No. 34 S)	5 feet
Clay, white, very sandy	3 feet

Result of Test.

This test was made at the Ceramic Laboratory of the University of Illinois under the direction of Prof. Cullen W. Parmelee.

Sample No. 34 S.

Received from Tennessee Geological Survey.

Collected by R. A. S.

Locality—Will R. Bobo, road exposure two miles north of Hinkledale.

Kind of material—A light-colored clay of a uniform character. It contains much sand.

Working property—Good, slightly sticky.

Water necessary to develop plasticity = 33.8 per cent.

Strength of unburned clay—Cross-breaking test. Modulus of rupture = 251.6 pounds per square inch.

Bonding strength with equal parts of standard sand—Cross-breaking test. Modulus of rupture = 174 pounds per square inch.

Slaking test = 17 minutes.

Fineness test:

20-mesh sieve	No residue
40-mesh sieve	No residue
60-mesh sieve	No residue
80-mesh sieve	No residue
120-mesh sieve, residue white sand and mica	0.4%
200-mesh sieve, residue white sand and mica	1.9%

Drying shrinkage, linear = 7.4 per cent.

Burning conduct:

	Color	Hardness	Total Shrinkage	Porosity
Cone 2	White	Steel hard	11.7%	27.9%
Cone 5	Light grey	Steel hard	15.1%	14.8%
Cone 9	Light grey	Steel hard	15.0%	10.3%
Cone 12	Light grey	Steel hard	16.7%	0.9%

Fusion test: Deforms at cone 31.

This clay burns to a very good color, but is rather open burning at cone nine for a ball clay. It has good strength in the unburned state and the rather high fusion test indicates that it may be of value as a ball clay in the manufacture of certain types of refractory wares. It may be used for the manufacture of such wares as terra cotta, sanitary ware, chemical stoneware, stoneware, face brick and saggers.

CARROLL COUNTY.

Topography.—Carroll County is situated in the northeastern part of West Tennessee. Its area is 624 square miles.

The Mississippi and Tennessee River divide crosses the county in a direction somewhat east of north, separating it into an eastern

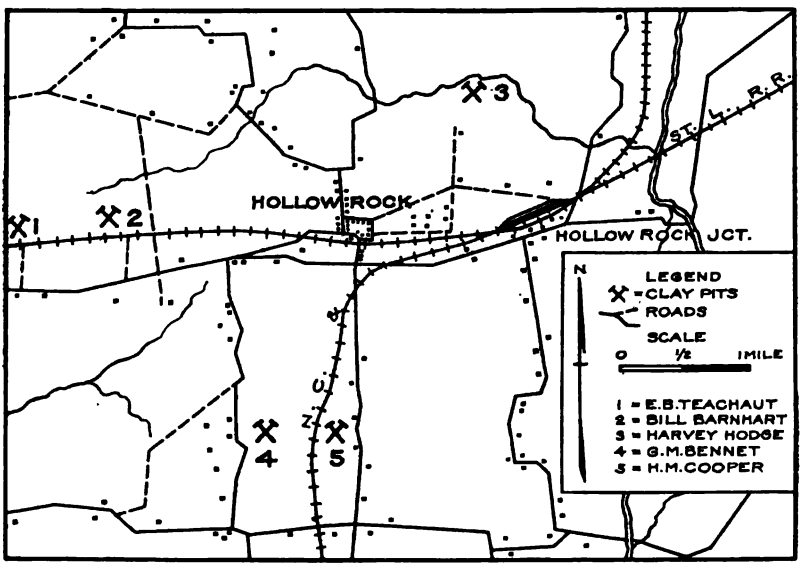

FIGURE 12—Map of Hollow Rock and vicinity, showing distribution of clay pits.

slope, which drains into Big Sandy and Tennessee Rivers, and a larger western slope, which drains into the Mississippi. The divide has an average elevation of 475 feet. The lowest elevation is 350 feet, at the points where the Big Sandy and South Fork of the Obion leave the county. The surface along the watershed is hilly and broken, for headwater erosion is active. The northern and western parts of the county are more level and the main streams here, as a rule, have broad, level flood plains and second bottoms.

CARROLL COUNTY PITS.

H. N. Cooper's Sagger Clay Pit.—This pit is situated on the Buena Vista Road, two miles south of Hollow Rock, on Mr. Cooper's farm. (See Fig. 12.) The clay is in the McNairy Sand Member, of the Ripley Formation (Upper Cretaceous), and has a light overburden consisting of pale brown unconsolidated sand. It underlies a low hill having an area of at least five acres; 121,000 tons of clay are estimated in the bank. The clay body is lens shaped, varying from five to fifteen feet in thickness. The clay is mined by hand and

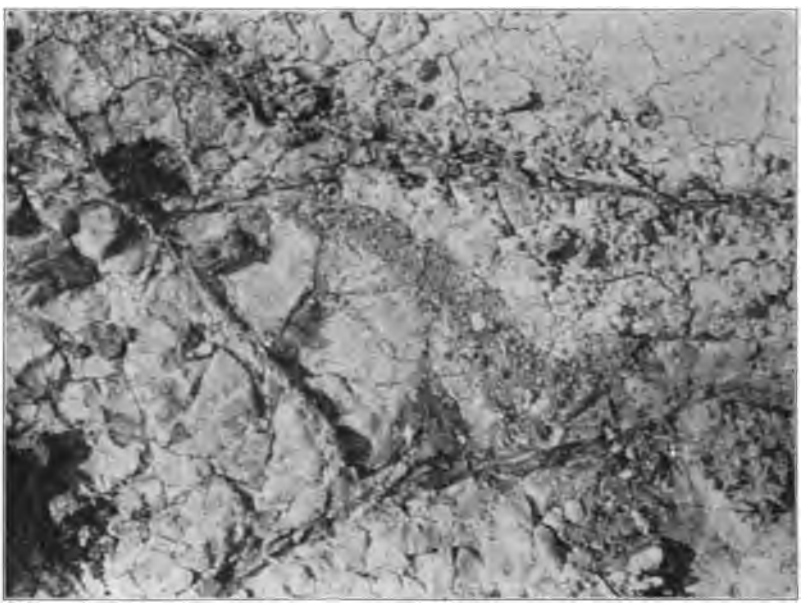

Photo by H. Ries.

FIGURE 13—Mud cracks, fossil and recent, in clay at Cooper's Pit, near Hollow rock.

carted to Hollow Rock for shipment. It is brown in color, being darkest in its lower portions, where it is somewhat lignitic in character and contains an abundance of fossil leaf impressions. The clay is slightly sandy and stratified throughout and is sold as sagger clay. Well preserved limonitic fossil mud-cracks of remarkable size occur in the upper horizons of the clay deposit on the south side of the pit. It is necessary to separate these from the clay before shipping. (See Fig. 13.) This clay was sampled as No. 2.

Result of Test.

This test was made at the Ceramic Laboratory of the University of Illinois, under the direction of Prof. Cullen W. Parmelee.

Sample No. 118. Tennessee Geological Survey No. 2.

Received from Wilbur A. Nelson, Tennessee Geological Survey.

Locality—Cooper Pit, Hollow Rock, Tenn.

Kind of Material—Plastic clay of a dark grey color, fairly hard, contains mica particles, feels sandy.

Working property—Good.

Water of plasticity = 33.9 per cent.

Strength of unburned clay—Cross-breaking test. Modulus of rupture = 138 pounds per square inch.

Bonding strength of a mixture of equal parts of standard sand. Modulus of rupture = 86.2 pounds per square inch.

Slaking test = 6 minutes.

Fineness test:

20-mesh sieve	No residue
40-mesh sieve	No residue
60-mesh sieve	No residue
80-mesh sieve	No residue
120-mesh sieve	Trace, chiefly mica
150-mesh sieve	0.04 per cent

Drying shrinkage, linear = 5.8 per cent.

Burning conduct:

	Color	Hardness	Total Shrinkage	Porosity
Cone 2	Pinkish	Steel hard	10.0%	29.1%
Cone 5	Pinkish	Steel hard	11.5%	25.0%
Cone 9	Dark grey	Steel hard	13.5%	6.1%
Cone 12	Dark grey	Steel hard	13.7%	5.7%
Cone 13		Steel hard		11.4%

Fusion test: Deforms at cone 30.

This clay shows a good vitrification at cone nine. The color is fair, the strength is also fairly good. It wil probably be of service in the manufacture of terra cotta, sanitary ware, face brick and saggers. It is doubtful that the color will be entirely satisfactory for use as a ball clay.

G. M. Bennet's Pit.—This pit is situated one-half mile northwest of the Nashville, Chattanooga & St. Louis Railway and about two miles southwest of Hollow Rock. The pit is worked intermittently. It is elliptical in shape, 180 feet long and sixty-five feet wide, and is now filled with water which could easily be siphoned off. The clay underlies a low hill, as usual, and has an area of at least one

acre, which would give 29,000 tons of clay available in the bank. The overburden is light, measuring from three to eight feet in thickness. The clay lies in the McNairy Member of the Ripley formation (Upper Cretaceous).

There are two strata in the clay body, an upper pale grey, plastic clay, which was sampled (No. 13 S) and a lower dark colored clay, which was not seen on account of the water in the pit. The upper bed is six feet thick and the lower is said to be the same.

Result of Test.

No. 13 S.—This clay was not deformed at cone twenty-seven and slakes in twelve minutes. It cannot be ranked with the highly refractory crucible clays. The transverse test showed a modulus of rupture of 265.2 pounds per square inch, which is high.

A preliminary test only was made on this clay, complete tests having been made only in cases where the clay seemed promising as a *highly refractory bond clay,* such as is used in the manufacture of glass-pots and crucibles (in demand by our government as a war mineral). The Survey hopes to make additional tests upon this sample.

Mrs. E. B. Teachaut's Pit.—This pit is situated two miles west of Hollow Rock on the Nashville, Chattanooga & St. Louis Railway and is the property of Mrs. E. B. Teachaut of Huntingdon. It is not now in operation and has been partly filled with slump material. It is circular in shape and measures 150 by 180 feet. The overburden is about twenty feet thick and consists of red, clayey sands, case-hardened, with clay pellets, ironstone concretions and a sprinkling of gravel. Mr. Henderson Hill, who is familiar with this pit, states that a well hole bored fifty yards north of the pit (in the direction of operation) encountered a thirteen-foot stratum of black clay at a depth of thirty-five feet, and another 150 yards to the north encountered the clay at a depth of 70 feet. He also says that black clay was found eighteen feet deep at a point fifty yards west of the pit. Accepting these figures we can estimate the total tonnage of unmined clay (up to the line where the overburden is 35 feet) to be 24,000 tons.

An auger hole showed the following section:

Ironstone hard-pan	1 inch
Clay,* white and plastic	1½ feet
Clay,* grey, becoming very dark and lignitic with depth	5½ feet

*These beds were sampled as No. 26 S.

Tests.

The tests show that this clay burns a dark cream color at ordinary potters' heat, which is too dark for a ball clay. It was not deformed at cone twenty-eight and slakes in three minutes. Hence it is not a refractory bond clay. This clay may prove to be of value mixed with some other type of clay.

A preliminary test only was made on this clay, complete tests having been made only in cases where the clay seemed promising as a *highly refractory bond clay*, such as is used in the manufacture of glass-pots and crucibles (in demand by our government as a war mineral). The Survey hopes to make additional tests upon this sample.

Bill Barnhart's Pit.—This pit is not now in operation. It has been described by Wilbur A. Nelson.[1] The following is an excerpt from his report:

"The pit is situated two miles west of Hollow Rock on the north side of the Nashville, Chattanooga & St. Louis Railway. (See map of Hollow Rock and vicinity.) The pit is owned by Bill Barnhart, of Hollow Rock. It is not now worked. The pit is about 100 feet wide, and extends into the hill for nearly 100 yards, and the bed has a thickness of seven feet. The clay extends back under the rest of the hill, which covered about ten acres.

The following is a detailed section of pit:

Section at Barnhart Pit, near Hollow Rock.

A sand, dark red, hardened at top which grades to a lighter color and finally into a yellow sand above the clay	20-25 feet
Clay greyish yellow, slightly gritty, no nodules	7 feet
Sand, fine yellowish white, extends down under clay.	

The clay is colored grey by the presence of a slight amount of organic matter. Very little iron is present, only enough to give it a slight yellow tinge. The clay is of a fairly uniform color, which gets darker toward the bottom of the deposit. It has a conchoidal fracture. No analysis has been made of this clay. Leaf impressions are found in certain layers, and the whole bed is slightly gritty, but no nodules of iron or any other mineral are present. The bed is massive, without joints, or thin sand layers to break up, and clay breaks in lumps of irregular size.

[1]Nelson, Wilbur A., The clays of West Tennessee, Tenn. Geol. Survey Bull. 5, p. 44.

This clay as well as all the others around Hollow Rock is in the upper part of the Ripley formation. The overlying sands are of the Lafayette formation of the Pliocene age, and in all these pits forms the overburden.

The overburden at the pit face is about twenty-five feet, and becomes heavier further back, the maximum being about thirty-five feet. The upper fifteen feet is very hard and difficult to remove, while lower down it is very easily removed, being a loose sand.

This pit is very accessible, as it is right on the Nashville, Chattanooga & St. Louis Railway, and only one-fourth mile from a switch where it can be loaded and shipped. The soil on top of the clay lens is covered with a light second growth timber, most of it still small."

This clay was sampled as No. 19 S. It was once mined and shipped to potteries and stoneware makers.

Tests.

Sample No. 19 S.—This clay is not deformed at cone twenty-seven and slakes in ten minutes. Transverse test—192.7 pounds per square inch.

A preliminary test only was made on this clay, complete tests having been made only in cases where the clay seemed promising as a *highly refractory bond clay*, such as is used in the manufacture of glass-pots and crucibles (in demand by our government as a war mineral). The Survey hopes to make additional tests upon this sample.

Harvey Hodge Pit.—This pit is situated about one and one-half miles northeast of Hollow Rock. It is leased and operated by A. Nunnely of Hollow Rock. The clay stratum is fourteen feet thick and underlies a low hill of two acres area. The overburden consists of unconsolidated sand, of Ripley age, zero to fifteen feet thick. On the present face of the pit it measures six feet thick and is easily removed by blasting and scrapers. The pit is elliptical in shape, 160 feet long by 100 feet wide, and is drained towards the northeast by a small gully. It is estimated that 68,000 tons of unworked clay remain in the bank.

Section.

Sand, unconsolidated	0-15 feet
Clay, white, plastic, massive (Sample No. 11)	7 feet
Clay, dark grey, stratified, with fossil leaf prints (Sample No. 1)	7 feet

The clay is hauled over a bad road to Hollow Rock, from which point it is shipped to West Virginia, Pennsylvania and Trenton, N. J., as sagger clay, under the commercial name "291."

Result of Tests.

This test was made at the Ceramic Laboratory of the University of Illinois, under the direction of Prof. Cullen W. Parmelee.

Sample No. 1, Tenn. Our Lab. No. 117.

Received from Tennessee Geological Survey.

Collected by Wilbur A. Nelson.

Locality—From 12-foot stratum of black clay of Nunnelly Pit on Harvey Hodge property, Hollow Rock.

Kind of Material—A dark grey, moderately hard clay.

Working property—Good, somewhat sticky.

Water necessary for plasticity = 31.6 per cent.

Strength of the unburned clay—Cross-breaking test. Modulus of rupture = 112 pounds per square inch.

Bonding strength of a mixture of equal parts of standard sand. Modulus of rupture = 112 pounds per square inch.

Slaking test = 5 minutes.

Fineness test:

20-mesh sieve	No residue
40-mesh sieve	No residue
60-mesh sieve	Trace of residue
80-mesh sieve	Trace of residue
120-mesh sieve, residue mica and sand	0.46%
150-mesh sieve, residue mica and sand	0.50%
200-mesh sieve, residue mica and sand	0.60%

Drying shrinkage, linear = 6.8%.

Burning conduct:

	Color	Hardness	Total Shrinkage	Porosity
Cone 2	White	Steel hard	16.5%	28.0%
Cone 5	White	Steel hard	13.7%	28.0%
Cone 9	Light cream	Steel hard	14.7%	22.1%
Cone 12	Light cream	Steel hard	15.8%	8.5%
Cone 13		Steel hard	16.2%	11.4%

Fusion test: Deforms at cone 31.

This clay burns to a good color at the various temperatures. It is a rather open burning for a ball clay and the strength of the unburned clay is only fair. It is more of a semi-ball clay in nature than a ball clay. It will doubtless be of service in the manufacture of certain grades of chemical stoneware, sanitary ware, terra cotta, face brick, saggers and possibly find some use as a bonding material

in the manufacture of certain refractories which are not expected to stand too high temperatures.

CARROLL COUNTY PROSPECTS.

Thompson and Barkdale Prospect.—Clay is exposed in gullies over a distance of a quarter mile on J. M. Barkdale's farm, two miles south of McKenzie. The nearest railway is only a half mile distant. The overburden consists of pale brown, unconsolidated sand having an average thickness of fifteen feet, but varies between zero and thirty feet. The clay deposit is large, underlying at least five acres (and possibly twenty-five, according to Mr. Porter of McKenzie, who has bored a number of test holes). A strong spring emerges from the upper surface of the clay bed. Mr. Thompson says that he encountered a thirty-foot stratum of clay at a depth of thirty-eight feet while sinking a well near his house nearby.

Auger Hole Section.

Sand, light brown, loose	12 feet
Clay, white, very plastic, not much grit (Sample No. 32 S)	9 feet
Clay, white and sandy (Sample No. 33 S)	9 feet

It is estimated that the upper stratum of clay contains 108,500 tons in the bank and the same for the lower.

Sample No. 33 S was considered too sandy to test.

The result of testing No. 32 S shows that the clay burns to a dark cream color which makes it unfit for a ball clay. Its slaking time was 120 minutes, which is very long. It is not deformed at cone twenty-seven, and hence is not to be included among highly refractory clays.

A preliminary test only was made on this clay, complete tests having been made only in cases where the clay seemed promising as a *highly refractory bond clay*, such as is used in the manufacture of glass-pots and crucibles (in demand by our government as a war mineral). The Survey hopes to make additional tests upon this sample.

Road Exposure.—Clay is exposed in a gully two and one-half miles north of Huntingdon on the east side of the road to Paris. The deposit is apparently a small one, this being the only outcrop visible. It consists of a lens shaped body underlying a wooded hill and dips 5° to 10° NW with the slope of the hill. The clay is unconformable with the overlying Lagrange sands and contains in its upper part an old stream channel now filled with sand and clay. The clay itself

is a poorly-bedded, plastic clay with a delicate pink color. A sample was collected and tested (No. 10 S). The clay lens pinches out towards the west but may underlie an acre or two towards the south.

Section.

Loess and sand, pale brown	4 feet
Sand, red and clayey, with clay pellets near the base	8 feet
Unconformity.	
Clay, pink and white, bedded	4-6 feet
Sand, dark orange and red, case-hardened, with concretions	10+ feet

Result of Test.

This clay was not deformed at cone twenty-five* and slakes in seven minutes. Hence it is not a refractory bond clay. It burns to a cream color at ordinary potter's heat, this being too dark for a good ball clay.

A preliminary test only was made on this clay, complete tests having been made only in cases where the clay seemed promising as a *highly refractory bond clay*, such as is used in the manufacture of glass-pots and crucibles (in demand by our government as a war mineral). The Survey hopes to make additional tests upon this sample.

Road Exposure.—A clay "blossom" was found in a ditch on the Huntingdon-McLemoresville Road, in front of Thomas Orman's house, about three miles west of Huntingdon. The clay dips slightly with the slope of the hill and has an overburden of three to eight feet of loose brown sand. The clay bed is at least three feet thick and is exposed for one hundred feet along the road. It is dark grey when fresh and very plastic. A sample (No. 16 S) was collected for testing, but the entire thickness of the stratum was not ascertained. There is a good natural drainage and plenty of opportunity for dumping overburden in case this deposit is ever exploited.

Result of Test.

This clay is deformed at cone twenty-seven and slakes in eighteen minutes, and is therefore not a refractory (ball) clay.

Bonding strength, 182.7 pounds per square inch.

Transverse strength test—654.8 pounds per square inch. These two tests show that this clay is uncommonly strong.

A preliminary test only was made on this clay, complete tests having been made only in cases where the clay seemed promising as a *highly refractory bond clay*, such as is used in the manufacture of

*To be confirmed.

glass-pots and crucibles (in demand by our government as a war mineral). The Survey hopes to make additional tests upon this sample.

Road Exposure.—A clay bed outcrops at the base of a hill just beyond the point where the Christmasville Road joins the McLemoresville Road, three and one-half miles west of Huntingdon, on Stanley Hall's land. The clay is six feet thick, but appears to thin out up the hill. It seems to hold its thickness in a direction at right angles to the road. The overburden varies in thickness from four to fifteen feet, and could be easily removed down the hillside. The clay weathers white and is deeply dissected by sun-cracks on exposed surfaces. The fresh clay is dark grey, plastic and free from grit. It was sampled and tested (No. 17 S). The nearest railway is at Huntingdon, three and one-half miles distant. The available tonnage in the bank cannot be estimated without further prospecting (boring).

Result of Tests.

This clay is not deformed at cone twenty-seven and slakes in forty-five minutes.

A preliminary test only was made on this clay, complete tests having been made only in cases where the clay seemed promising as a *highly refractory bond clay,* such as is used in the manufacture of glass-pots and crucibles (in demand by our government as a war mineral). The Survey hopes to make additional tests upon this sample.

L. L. Wilson Prospect.—A clay blossom is exposed in an old railway cut, four miles west of Huntingdon on L. L. Wilson's land. The following section was noted at the road:

Clay, sandy, brown	5-20 feet
Clay, pink and rusty, much sand	5 feet
Clay, white, with pink and yellow stains, fibrous fracture, some rusty portions; appears to improve with depth. (Sample No. 100 S)	5+ feet

This stratum turns to a ferruginous clayey sand thirty-five to forty feet towards the northeast and appears to underlie a hill of several acres area on which Mr. Wilson's house is situated. Prospecting holes should be bored in a northwesterly direction on the summit of the hill. Many springs emerge on all sides from the base of the hill.

Road Exposure.—A good outcrop of white clay was seen on the Huntingdon-McLemoresville road, near Robert Bryant's house, about four miles west of Huntingdon.

The clay is exposed up a hill along the road for a distance of 220 feet, and appears to underlie a large area on Mr. Bryant's farm. It is six feet thick and was sampled for preliminary testing (sample No. 15 S). The clay is white with pink streaks and moderately plastic.

Result of Tests.

This clay deforms at cone twenty-seven and slakes in eight minutes. Hence it cannot be considered a refractory (ball) clay. Moreover it burns to a cream color at ordinary potter's heat, which is too dark for ball clay.

A preliminary test only was made on this clay, complete tests having been made only in cases where the clay seemed promising as a *highly refractory bond clay*, such as is used in the manufacture of glass-pots and crucibles (in demand by our government as a war mineral). The Survey hopes to make additional tests upon this sample.

Gully Exposure.—A good exposure of clay was found in a gully on the road to Hodge's Pit, behind a church, one-half mile from Hollow Rock. It is delicate pink in color, plastic and free from grit. A sample was collected for testing (No. 14 S). The stratum is four feet thick and carries an overburden of five to fifteen feet. The clay is exposed over a horizontal distance of fifty feet. It underlies at least one acre. The estimated tonnage of clay in the bank is 10,000.

Result of Tests.

This clay is not deformed at cone twenty-five* and slakes in six minutes. Hence it is not refractory. It burns to a cream color at ordinary potter's heat, and cannot be considered a ball clay. (Ball clays should burn white.)

A preliminary test only was made on this clay, complete tests having been made only in cases where the clay seemed promising as a *highly refractory bond clay*, such as is used in the manufacture of glass-pots and crucibles (in demand by our government as a war mineral). The Survey hopes to make additional tests upon this sample.

Bedwell's Prospect.—A good exposure of clay was found in a gully on Elbert P. Bedwell's farm, five miles south of McLemoresville. The clay is five feet thick and underlies a hill of several acres area. The overburden varies between twelve and fifteen feet in thickness and could be easily removed. It consists of loose brown sand.

*To be confirmed.

The clay is plastic, smooth and has a beautiful pink color with occasional yellowish blotches. It is underlain by a white sugary quartz sand. A sample (No. 21 S) was collected for testing. Unfortunately this deposit is very remote from a railway, the haul under present conditions being eight miles. Timber is abundant and the drainage is good. The estimated tonnage of clay in the bank is 24,000. The tests show that this clay burns to a light buff color at ordinary potter's heat and therefore should be of value to potters so far as color is concerned. It is not deformed at cone twenty-seven and slakes in eight minutes. It is not very refractory.

A preliminary test only was made on this clay, complete tests having been made only in cases where the clay seemed promising as a *highly refractory bond clay*, such as is used in the manufacture of glass-pots and crucibles (in demand by our government as a war mineral). The Survey hopes to make additional tests upon this sample.

S. W. Williamson Prospect.—Several hundred yards from the deposit just described we find a thick bed of white sandy clay. A sample was collected for testing (No. 22 S), but was considered too sandy to warrant further investigation.

Hayward Priest Prospect.—A small bed of clay is exposed on the middle road to Paris, about one and one-half miles north of Huntingdon, near Anthony Coleman's (col.) house. The clay body extends towards the north under Mr. Priest's land. It is at least three feet thick and is exposed along the road for a distance of 225 feet. The clay is pale grey but weathers white. The overburden is not heavy and will nowhere exceed ten feet. An auger hole was bored to procure a sample for testing. (Sample No. 23 S.)

Result of Tests.

This clay deforms at cone twenty-eight and slakes in eight minutes. It is therefore not very refractory, but burns to a light buff color at ordinary potter's heat, and hence may be of interest to this industry.

A preliminary test only was made on this clay, complete tests having been made only in cases where the clay seemed promising as a *highly refractory bond clay*, such as is used in the manufacture of glass-pots and crucibles (in demand by our government as a war mineral). The Survey hopes to make additional tests upon this sample.

The "Huckleberry Schoolhouse" Prospect.—A large deposit of clay outcrops in a gully system east of the schoolhouse, three miles south

of McLemoresville. The clay underlies an area of about eight acres. The estimated tonnage available in the bank is 240,000.

Section.

Sand, red-brown	10 feet
Clay, grey-brown, plastic, stratified (Sample No. 18 S)	12 feet
Ironstone layer	1 inch
Clay, sandy and ferruginous	Depth not ascertained

Result of Test.

This test was made at the Ceramic Laboratory of the University of Illinois, under the direction of Prof. Cullen W. Parmelee.

Sample No. 18 S.

Received from Tennessee Geological Survey.

Collected by R. A. S.

Locality—Road and gully exposure, three miles south of McLemoresville near T. A. Younger's farm.

Kind of Material—A greyish-cream colored clay of a uniform character. It is moderately hard and contains mica particles and fine sand.

Working property—Good, not sticky.

Water necessary to develop plasticity = 46.7 per cent.

Strength of unburned clay—Cross-breaking test. Modulus of rupture = 597.6 pounds per square inch.

Bonding strength with equal parts of standard sand—Cross-breaking test. Modulus of rupture = 156 pounds per square inch.

Slaking test = 21 minutes.

Fineness test:

20-mesh sieve	No residue
40-mesh sieve	No residue
60-mesh sieve	No residue
120-mesh sieve, residue white sand	0.01%
200-mesh sieve, residue white sand	0.33%

Drying shrinkage, linear = 10.83 per cent.

Burning conduct:

	Color	Hardness	Total Shrinkage	Porosity
Cone 2	Light buff	Steel hard	13.7%	22.5%
Cone 5	Light buff	Steel hard	17.1%	14.2%
Cone 9	Dark grey	Steel hard	18.7%	9.2%
Cone 12	Dark grey	Steel hard	19.5%	3.3%

Fusion test: Deformed at cone 27.

The color of this clay burned at cone nine is fair. The strength is very high. It is not sufficiently refractory for use as a refractory bond clay. The clay may be used in the manufacture of terra cotta, chemical stoneware, stoneware, face brick and saggers and abrasives.

The Murray Gilchrist Prospect.—A large deposit of promising looking pink clay is exposed in several large gullies, three-fourths of a mile from John Smith's house, west of Gilchrist Lane, and four miles south of Trezevant. This place was formerly known as the William Watkins place. This deposit has been examined by Mr. Wilbur Nelson, State Geologist. The following is an excerpt from his report:[1]

"In the gully farthest south just before the road goes down the hill, the following section was viewed:

Section near Trezevant.

Lafayette—Light orange sandy clay, no gravel	6 feet
Lagrange—Darker orange case-hardened, cross-bedded sand, very little clay	5—7 feet
A very good white clay, exposed to bottom gully	12 feet

In another gully 100 feet north of the former and back from the road, another good exposure was found, as follows:

Section West of Trezevant.

Lafayette—Clay, light orange sandy	5 feet
Lagrange—Sand clay, cross-bedded, dark orange, case-hardened whitish clay pellets scattered through it	12 feet
Clay, white, exposed to bottom of gully	3 feet

The lower bed of white clay, of which only the top is exposed, is one of the best plastic clays, which was found outside of Henry County. This clay undoubtedly extends down at least four or five feet below the bottom of the gully, and should change into a better quality. In places a slight pink mottling is visible, but there is not an injurious amount of iron present. The clay has a fine conchoidal fracture. There is no grit or sand present, and no concretions or nodules of any kind were found.

This clay lens lies in the middle part of the Lagrange formation. The unconformity between that bed and the Lafayette lies between the soft light orange sandy clay, and the hard cross-bedded dark orange sand, which overlay the clay. The clay appears to extend northward from the exposure, and probably covers only three or four acres.

Outcrops can be found in most of the gullies around this locality on all sides of the hills, which will aid materially in determining the extent of the clay lenses. Any pit here could be easily drained.

The overburden, which will vary from seventeen feet at the outcrop to about twenty-five feet under the hill, is at the top a loose sandy

[1]Nelson, Wilbur A., Clays of West Tennessee, Tenn. Geol. Survey Bull. 5, p. 54.

clay, easily removed. Below this is a bed of sand, case-hardened, which could be removed without much difficulty. This outcrop is four miles by road to Trezevant and two and three-fourths miles by nearest road to the railroad, four miles south of Trezevant.

No clay has been dug at this point and no other good exposures were seen, but prospecting done in this locality would undoubtedly uncover some good ball clay deposits."

The clay in the first gully, nearest the road, underlies about one acre of land and should yield 29,038 tons. It was sampled for testing (No. 24 S). The clay in the other gully, 100 feet towards the north, underlies about two acres and should yield 24,000 tons in the bank. (No. 25 S.)

Result of Tests.

A preliminary test only was made on this clay, complete tests having been made only in cases where the clay seemed promising as a *highly refractory bond clay*, such as is used in the manufacture of glass-pots and crucibles (in demand by our government as a war mineral). The Survey hopes to make additional tests upon this sample.

Clay No. 24 S.—This clay burns to a light cream color at ordinary potter's heat. It is not deformed at cone twenty-eight and slakes in seven minutes. It should make a good ball clay although it is not highly refractory.

Clay No. 25 S.—This clay also burns to a light cream color. It is not deformed at cone twenty-eight and slakes in nine minutes. Thus it is very similar to No. 24 S and should find a market in the pottery industry.

Hoffman Deposit.—There is an exposure of white clay in a small gully about one-fourth of a mile from Hico, on Mr. Hoffman's farm. The overburden is light, being less than fifteen feet thick, and is composed of orange colored, case-hardened sand. The clay is weathered to a white, chalky color and consistency. An auger hole was bored and gave the following section:

Sand, orange, extremely hard	12 inches
Clay, pale grey, sandy	6 inches
Ball clay, grey	8 inches
Ball clay, yellow-brown	4 inches
Sandy clay	

No sample was collected. The Johnson-Porter Clay Company of Paris, has recently bored a number of prospecting holes and discov-

ered a considerable deposit of their No. 10 and No. 11 ball clay. They have acquired the property and have begun to develop it.

Gully Exposure.—Clay is exposed in numerous large gullies one quarter of a mile west of Buena Vista. The clay underlies about five acres, is very dark and micaceous in character, and was not sampled. It is in the McNairy Sand Member of the Ripley formation (Upper Cretaceous).

Section.

Sand, pale orange and brown, containing hard-pan beds .....0 to 20 feet
Clay, black, greasy and micaceous, containing marcasite nodules.... 12+ feet

"Pyrite Mine."—A small abandoned mine exists on a hillside on Taylor Bennet's land, two and three-fourths miles north of Huntingdon on the Paris road. It is in the Porters Creek formation of Eocene age. The excavation is about thirty feet long by ten feet wide and three feet deep, and is now filled with water. Several wagon loads of marcasite nodules (iron disulphide) have been mined by Mr. Hayden B. Gunter and piled up near by. None has ever been shipped. It would hardly pay to mine these nodules, for the quantity is too limited.

Marcasite Nodules.—Another deposit, very similar to the foregoing, is situated on Mr. Spencer Clark's farm, three and a half miles northwest of Huntingdon. The black Porters Creek clays outcrop in a ravine at the base of a fifty-foot hill. The quantity of marcasite here is also too small to be of any economic importance.

Section on a hillside two miles north of Huntingdon on the Paris road.

Lagrange—Brown, case- hardened sands, containing thin ironstone strata and a small sandy bed of white clay.....	7 feet
Porters Creek—Red, clayey, micaceous sand, containing large nodular ironstone concretions, up to four feet in diameter and occasional crystals of gypsum of minute size. This stratum probably represents reworked Porters Creek material and might possibly be called basal Lagrange	4 feet
Typical, micaceous Porters Creek clay showing concentric fracture, etc. Exposed over a horizontal distance of 175 feet.....	30 feet

MADISON COUNTY PROSPECTS.

Road Exposure.—There is a promising looking clay blossom five miles northeast of Jackson on the Brown's Church Road. The clay stratum underlies a hill towards the southwest and may cover four or five acres. There is about a foot and a half of ball clay which may thicken under the summit of the hill, as is usually the case. Since

the overburden nowhere exceeds twenty feet it would be well to bore prospecting holes on the top of the hill. The overburden consists of unconsolidated sands, pale orange in color, and measures from five to twenty feet in thickness. The nearest railway is at Jackson, five miles distant over an excellent road. The clay is in the Lagrange formation of Eocene age.

Auger Hole Section.

Clay, grey and rusty, very sandy	1 foot
Clay, chocolate brown and lignitic	½ foot
Clay, same color, less lignitic in character, very plastic and free from grit; poorly bedded	1½ feet
Clay, grey, sandy and stratified	1 foot

Road Exposure.—One-half mile beyond the outcrop just described there is a small bed of rose and yellow colored sandy clay. It is merely a clay blossom and of no economic importance.

Road Exposure.—Two clay deposits outcrop on the Milan Road, two and three-fourths miles north of Jackson. They are similar in character and one section will answer for both.

Section.

Sand, red, case-hardened and strongly cross-bedded, containing clay pellets	0-12 feet
Unconformity	
Clay, grey and rusty, very sandy, weathers to a chalky white. This clay would hardly be worth mining except for whitewash	5-12 feet

Gully Exposure.—A twelve-foot stratum of clay outcrops near the Denmark-Bells Road, about three and a half miles northwest of Denmark. This stratum consists of white, chalky clay interstratified with cream-colored, strongly cross-bedded sands, upon whose projecting edges the clay has formed small stalactites. No clay of any value was found here.

Road Exposure.—A small bed of pink, fossil-leaf bearing clay was found on the Huntersville-Denmark Road, three miles north of Denmark. The clay alternates with beds of white sand and is of no commercial value. It is in the Lagrange formation of Eocene age.

Sam Reid Prospect.—One-quarter mile south of Denmark on the land of Sam Reid (colored) a large deposit of clay may be seen outcropping in numerous gullies.

Auger Hole Section.

Sand, pale brown, with occasional beds of pure transparent quartz sand	0-5 feet
Clay, white with red and yellow discolorations, sandy	15 feet
Clay, white and claret red, plastic and less sand than above	5 feet
Sand.	

This lower stratum may possibly be used for sagger clay, but would not be suitable for ball clay.

L. Marks Prospect.—The following section was noted in a railroad cut, one-half mile south of Oakfield on the Illinois Central Railroad, on property of L. Marks of Jackson.

Lafayette—Red, case-hardened sand	10 feet
Lagrange—Sand, orange, cream and white, with a scattering of clay pellets and ironstone concretions. There are several very thin beds of white clay, interstratified with the sand but of no value	15 feet

Gully Exposure.—Clay outcrops in a large gully on the Deep Gap Road, five miles southeast of Jackson.

Section.

Columbia—Pale brown, earthy sand	3-5 feet
Lafayette—Sand, red, case-hardened, cross-bedded with clay pellets	0-20 feet
Lagrange—Clay, well stratified, white and sandy, stained yellow in places and traversed by a vertical joint system	10 feet

The bulk of the clay lies to the northeast of this exposure. It might be used for a fire brick clay if it occurs in large quantities. Prospecting holes should be bored to determine its extent.

Sternberger Prospect.—An extensive deposit of clay may be seen outcropping in a gully system, two miles south of Neely Station, on the old Williamson place. About five acres of sand and clay have been eroded and transported, leaving a good exposure. At least ten acres of clay remain in place, for it appears to extend to the old Utley place, one-half mile towards the northwest.

Section.

Sand, brown and red, containing ironstone concretions up to one foot in diameter and hardpan layers	7 feet
Unconformity.	
Clay, white with rusty discolorations, well stratified and very sandy. Surface abounds with "miniature hoodoos" (see below)	0-5 feet
Local unconformity.	

Clay, flesh red to pale pink and grey-pink, occasional yellow streaks, bedded. The clay is moderately plastic and free from sand, the bedding planes containing a thin film of dust. It has a greasy feel. Was sampled as No. 62 S. The stratum is very irregular, pinching out entirely here, widening to six feet there. Average thickness	3 feet
Hardpan	1 inch
Sand, white and brown	4+ feet

The chief objection to this clay is its very un-uniform character and the presence of stratification.

A curious erosion feature may be seen on the surface of this clay bed, as well as on many others in West Tennessee. Rapid erosion, accomplished by torrential rains, has carved out little cylindrical clay columns, tapering upwards, and capped by a protective leaf, fragment of hardpan, stick, or most any little piece of flat material. These are generally under six inches in height and make an interesting spectacle when crowded together in large numbers, like so many soldiers. The writer has referred to them as "miniature hoodoos."

Result of Test.

A preliminary test only was made on this clay, complete tests having been made only in cases where the clay seemed promising as a ***highly refractory bond clay***, such as is used in the manufacture of glass-pots and crucibles (in demand by our government as a war mineral). The Survey hopes to make additional tests upon this sample.

Transverse test—252 pounds per square inch (high). This clay is deformed at cone thirty-one and slakes in ten minutes.

Dr. A. B. Dancy Prospect.—Two thin beds of white ball clay outcrop in gullies on Dr. Dancy's land, two miles east of Jackson on the Lexington Road. The clay should be suited for ball clay, for it is said to burn white. It may thicken under the hill to the south, in which case it would be well worth mining. The railway is only two miles distant over an excellent road. The following section was noted:

Section.

Columbia—Brown clay and sand	1½ feet
Lafayette—Red, case-hardened sand	5½ feet
Lagrange—Orange and cream-colored sands, strongly cross-bedded, with clay pellets	10 feet
Clay, white and pink, very plastic and very little sand, occasional streaks of yellow	2 feet

Road Exposure.—A five-foot stratum of white, sandy, stratified micaceous clay was seen in the Lagrange sands, two miles south of Medon, on the Jackson-Pine Top Road.

Road Exposure.—Two small white, sandy clay blossoms were seen at a point three miles north of Beachbluff and one mile west of Bear Creek.

W. J. Cathey Prospect (R. F. D. 7).—Mr. Cathey submitted a sample of white clay which was very sandy. The deposit was not visited.

W. M. Kelley Prospect.—Mr. Kelley claimed to have a fine grade of clay, twelve miles from Jackson on the Clay Brook Road. A long search was made for this deposit but no clay was found.

Gully Exposure.—Clay is exposed in a large gully on the east side of the Bemis-Denmark Road, eight miles southwest of Jackson. The clay is six to eight feet thick and is white in color. It is too sandy to be of any use except possibly for fire clay or whitewash. It has washed down upon the subjacent sand strata, covering the latter with a thin white crust and hanging from projecting points in stalactites. The overburden is red sand, ten to fifteen feet thick.

MADISON COUNTY SECTIONS.

Section in gully, on west side of road about two hundred yards north of the outcrop just described.

Columbia—Pale brown, earthy sand	3 feet
Lafayette—Dark red, case-hardened sands, standing up in knife-edge fashion, vertical-walled	10-15 feet
Hardpan	3 inches
Lagrange—Sand, yellow, brown and cream-colored, containing clay pellets up to one foot in diameter and thin beds of white, sugary quartz sand	20 feet
Clay, small lens of grey and pink, sandy	1 foot

Section on Pinson Hill.

One mile northeast of Pinson.

Lafayette—Red sand	4 feet
Lagrange—Yellow and cream sands	2 feet
Porters Creek—Typical micaceous, sandy clay, with three-inch sandstone dikes and a dike-like mass of sandstone fifteen feet wide (exposed near the summit)	50 feet

Section Near Bear Creek.

Two and a half miles southwest of Pinson.

Lafayette—Brilliant red and vermillion-colored, case-hardened sands	12 feet
Lagrange—Sand, orange and brown, containing ironstone concretions and clay pellets	4-8 feet
Clay conglomerate (see Fig. 4). White clay pellets in a matrix of orange sand. In places the sand has washed out leaving the clay standing in the form of miniature hoodoos	8-18 feet

Section Two Miles South of Medon on Bolivar Road.

Lafayette—Red, hard, clayey sand	10 feet
Lagrange—Brown, cream and white beds of sand, alternating; clayey	10 feet
Clay, white, with yellow stains, sandy, micaceous and well-bedded	6 feet
Local unconformity.	
Clay, grey, well-bedded, rich in mica and sand, containing fossil mud cracks	6 feet

It is said that this white clay was once used in Jackson as pottery clay.

HAYWOOD COUNTY.

W. S. Lea Prospect.—Clay outcrops in a railway cut of the Louisville & Nashville Railway five miles northeast of Brownsville, on W. S. Lea's property.

The clay underlies a hill of ten acres and Mr. Lea has bored several test holes and finds it persistent. It occurs in two strata. The upper stratum is white, with red and yellow discolorations, slightly sandy and not very plastic. (Sample No. 60 S.) It is six feet thick. The lower bed is ball clay, but is only one and a half feet thick. It is brown, lignitic and plastic, resembling Mandle's Tennessee Ball Clay No. 5 in places. (Sample No. 61 S.)

The overburden is light (average ten feet). If the upper bed proves to be suitable for mining, the lower bed could probably be sold as ball clay. As the railway is right there the expense of hauling would be obviated. The brown clay was one of the best and most plastic found outside of Henry County.

Result of Tests.

A preliminary test only was made on this clay, complete tests having been made only in cases where the clay seemed promising as a *highly refractory bond clay*, such as is used in the manufacture of glass-pots and crucibles (in demand by our government as a war mineral). The Survey hopes to make additional tests upon this sample.

No. 60 S.—This clay is deformed a tcone thirty-three (high) and slakes in nine and one-half minutes. It burns a light tan color. Transverse test—371.8 pounds per square inch (this is high, 150 pounds being high enough for ball clays).

No. 61 S.—This clay is deformed at cone thirty-three and slakes in twenty-two and one-half minutes.

HARDEMAN COUNTY.

Western Hospital Prospect, Bolivar.—A good exposure of plastic clay occurs in some gullies about one-half of a mile southwest of the Insane Asylum on the State's land. The following section was noted:

Sand, pale orange, clayey, soft at top, hardened at base, a little gravel at top	10-20 feet
Gravel, pebbles are quartzite, up to one inch in diameter	1½ feet
Clay, white, stained yellow in places, sandy and nonplastic	6 inches
Clay, rose, plastic, not very sandy, some mica and poorly bedded, conchoidal fracture (Sample No. 63 S)	3 feet
Clay, somewhat inferior in quality	2 feet

The clay lens underlies a hill towards the east, which extends 20° west of north. Test holes should be bored towards the east near the summit of the hill.

The clay is only two and a half miles distant from the nearest railway. Thus the expense of hauling would not be great.

Result of Tests.

This clay deforms at cone thirty-one and slakes in four and one-half minutes.

A preliminary test only was made on this clay, complete tests having been made only in cases where the clay seemed promising as a *highly refractory bond clay*, such as is used in the manufacture of glass-pots and crucibles (in demand by our government as a war mineral). The Survey hopes to make additional tests upon this sample.

Section Five Miles East of Bolivar on the Bolivar-Purdy Road.

Columbia—Pale brown clay and sand	2 feet
Lafayette—Brown and red, case-hardened sands with thin bed of hardpan	10 feet
Lagrange—Reddish-brown and brown sand, containing strata of clay conglomerate towards base. The pebbles are dark grey clay up to two feet in diameter, and somewhat resemble the subjacent Porters Creek clay	38 feet
Unconformity.	
Porters Creek—Typical micaceous clays exposed to creek bottom	15 feet

FAYETTE COUNTY.

McNanee Pit.—This pit is situated one-half mile west of Lagrange near the Southern Railroad and is the property of Miss Anna McNanee of Memphis. It is not now working. The pit covers about five acres and is not exhausted, about five acres of clay remaining unworked. The clay was mined in 1916 and shipped to potteries. The overburden consists of red and brown loess and sands of Lafayette age and measures eight to ten feet in thickness. The clay is pink and grey, with yellow limonitic discolorations. It is sandy and moderately plastic when wet. Ten to twelve feet are exposed but its entire thickness was not ascertained. The clay was not sampled.

J. B. Sims Prospect.—A good clay deposit was found two and a half miles west of Lagrange on the Moscow Road alongside the Southern Railroad. The clay is exposed for 100 feet along the road and appears to underlie a hill to the south. The overburden is composed of brick red sand and averages ten feet in thickness.

Auger Hole Section.

Clay, white to grey, with pale pink and yellow discolorations, sandy	5 feet
Clay, same, not so sandy and moderately plastic (Sample No. 64 S).....	5 feet
Clay, sandy, inferior quality	5+ feet

Result of Tests.

A preliminary test only was made on this clay, complete tests having been made only in cases where the clay seemed promising as a *highly refractory bond clay*, such as is used in the manufacture of glass-pots and crucibles (in demand by our government as a war mineral). The Survey hopes to make additional tests upon this sample.

Transverse test high (312.4 pounds per square inch). Fusion test—deformed at cone twenty-nine (refractory).

J. F. Dale Sand Pit.—This pit is situated about one mile southwest of Lagrange and reached by a narrow gauge railroad. The sand is shipped to plate glass and concrete manufacturers. The pit is nearly 100 feet deep, the sand being hauled up an incline in tram cars by means of a steam-hoist. It covers several acres.

Section.

Loess	3 feet
Sand, red-brown, somewhat clayey, known commercially as No. 2....	15 feet
Unconformity.	

Clay, white, sandy, micaceous and plastic	4-7 feet
Unconformity.	
Sand, much lighter than the upper stratum, white, cream and pink, with occasional streaks of orange and purple, unconsolidated and cross-bedded. (The white sands are known as No. 1.)	65 feet
Sand, dark red, with clay pellets up to one foot long, composed of white, very plastic and pure clay	2 feet

The clay stratum is discarded but ought to find a market, for the clay has to be mined anyway.

McNAIRY COUNTY.

P. H. Thrasher Prospect.—Mr. Thrasher reports an occurrence of white, plastic clay near his fish pond one-half mile northwest of Selmer. This clay stratum was encountered in digging an outlet for the pond. It is not now visible. Several auger holes were bored but no good clay could be found.

Hole No. 1.—Twenty yards east of the pond and twenty yards south of the outlet:

White sand, slightly argillaceous	5 feet
Sand, saturated with water	5+ feet

Hole No. 2.—Twenty yards southwest of Hole No. 1, directly adjacent to dam:

Dark-colored sand	1 foot
Clay, white to grey, very sandy	8 feet
Sand, brown and reddish	1 foot

Purdy Prospects.—A fine grade of clay is supposed to exist near Purdy, but no clay of superior quality was seen in and about the town. Only several thin strata of white sandy clay could be found and a peculiar grey clay was exposed in a gully 200 yards east of Purdy store.

Section Near Store.

Lafayette—Dark red, clayey sand	6 feet
Ripley—(McNairy sand member) brown and red sand	4 feet
Clay, pale grey, with yellow and red, ferruginous discolorations, rich in sand and muscovite	3-10 feet
Hardpan (said to underlie whole town)	4 feet
Sand, light brown, exposed to bottom of gully	4 feet

The formations dip gently eastward with the slope of the hill.

Falcon Exposures.—Clay outcrops over a large area in a gully system three-fourths of a mile east of Falcon. It underlies a hill of about twenty acres, but is of inferior quality.

Section.

Columbia—Pale brown sand and loam	½-2 feet
Lafayette—Liver-red sands, with occasional white quartzite pebbles up to ½-inch in diameter	5-20 feet
Unconformity.	
Ripley (McNairy sand member)—Clay, grey, very sandy, containing mud cracks and red, sandy streaks	5-8 feet

Section one and one-fourth miles west of Picket's Store (five miles east of Finger).

Unconformity.	
Sand, red, case-hardened	15 feet
Sand, white, alternating with thin beds of poor, white clay. The clay is stained red and yellow by iron and contains muscovite mica	2 feet
Sand, white, pink and cream, cross-bedded, containing thin hardpan layers	20 feet

A. Plunk Prospect.—Clay is exposed in gullies in the rear of Mr. Plunk's house, four miles east of Finger. It is too sandy to be of value.

Section.

Pale brown, case-hardened sands, containing thin hardpan layers	15 feet
Clay, grey and rose, stained yellow, very sandy, and micaceous	3 feet
Sand, brown	10 feet

A similar occurrence was found one-fourth of a mile south of here on E. H. Jones' farm. A three-inch stratum of hardpan underlies the clay.

HENDERSON COUNTY.

J. A. Threadgill Prospect.—Clay is exposed in the roadbed, twelve miles west of Lexington on the Jackson Road on Mr. Threadgill's land. The clay has been mined and used in the manufacture of jugs.

Section.

Columbia—Brown, loamy sand	2 feet
Lafayette—Red, hard sand	5 feet
Lagrange—Clay, white, sandy and stratified	6+ feet

E. L. Fesmire Prospect.—There are several outcrops of clay on Mr. Fesmire's land, five and a half miles northwest of Lexington, and three miles west of Timberlake.

Section Near Road.

Sand, orange and red, micaceous, well cross-bedded	10 feet
Unconformity.	
Sand, yellow, pink and purple, alternating with thin beds of grey clay	12 feet
Black clay	3 feet

Lignite interbedded with white quartz sand, rich in muscovite and containing marcasite nodules	4+ feet

At a point 300 yards northwest of here clay is exposed on a hillside. This clay was once mined for pottery purposes.

Auger Hole Section.

Sand, clayey, brown	4-10 feet
Clay, grey with yellow and red discolorations, sandy, stratified	6 feet
Clay, dark brown to grey, contains finely disseminated mica and sand and occasionally a thin bed of white and yellow sand	8 feet
Clay, same only sandier and more rust	1 foot

The eight-foot stratum should make a sagger clay. The overburden is light and the distance to the nearest railroad is only three miles. (Timberlake, on the Nashville, Chattanooga & St. Louis Railway.)

A. M. Power's Prospect.—A considerable deposit of clay occurs at a point one-half mile northwest of Reagan on Mr. Power's land.

Section.

Sand, brown, unconsolidated	5 feet
Sand, dark red and purple, partly case-hardened, containing small elongated clay pellets and large fluted bodies of ironstone	2-5 feet
Unconformity.	
Clay, grey and sandy, weathers white	2-5 feet
Sand, cream, orange and white, unconsolidated, exposed to bottom of gully	6 feet

The clay underlies a hill to the southeast and appears to thicken as it goes under. The axis of the hill trends N 40° E. The nearest railway is twelve miles distant, which fact, added to the rather inferior quality of the clay, would make its development unadvisable.

Road Exposure, one-half mile west of Lexington on Jackson Road.

Sand, red and brown	10-25 feet
Clay, white and grey, very sandy and micaceous, stratified	8-10 feet

Porters Creek and Selma Clay Outcrops.

Porters Creek.—At "Pyrite Mine," two and three-quarter miles north of Huntingdon on Taylor Bannet's land.

At base of hill on Spencer Clark's land, three and one-half miles northwest of Huntingdon.

On Mr. Wimpel's land, on Deep Gap and Mason Well Cross roads, east of Jackson.

On M. G. Hodges' land, on the Jackson-Heart Bridge Road, nine miles southeast of Jackson.

At the seven-mile post on the Jackson-Miflin Road (not seen).

In front of J. H. Treadgill's house, ten miles west of Lexington on Jackson Road.

On Mrs. H. Roark's place, nine miles west of Henderson, on Bolivar Road.

At Garret's Divide, in cut on new roadbed of the M. & B. O. Railroad.

Selma Clay.—At Hurricane Creek, three miles west of Sardis.

On the Reagan Road, one and a half miles north of Sardis.

On the Selmer-Pleasant Site Road, one mile north of Pleasant Site.

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Characteristic Properties of Ball and Plastic Refractory Bond Clays

By Cullen W. Parmelee.

Two of the important purposes served by testing clays are the saving of time and of money. Through the neglect of this elementary precaution many mistakes have been made which could easily have been avoided. Good material has been wasted and inferior material has been sold for purposes for which it was entirely unsuited. Perhaps, an even more important reason for the testing of clays is the great advantage and the necessity for knowing more about our national resources in order to be able to furnish native materials for our domestic industries. The cessation of importations of certain clays due to the war has shown very clearly that our former dependence upon them was unnecessary and highly undesirable. The necessity for finding native clays suitable as substitutes has been a valuable experience for the country.

The testing of clays affords a means of classifying them according to their probable usefulness in the various industries. The potter requires white burning clays for the manufacture of wares. Therefore a clay which burns white may be considered as of possible value for such a purpose. Ability to resist high temperatures without fusion is the chief characteristic of the refractory clays used in the manufacture of fire brick, glass-pots, graphite crucibles and other similar wares. Numerous other examples may be cited to illustrate the general scheme of classification. Any real systematic classification becomes much more complicated than these simple examples owing to the very complex character of clay. No two clays are exactly alike, and a proper understanding of the difference is essential in the choice and use of them in the manufacture of all important clay products.

The purpose of clay testing is to obtain as complete knowledge as possible regarding the peculiarities and special usefulness of each clay. To this end, methods of testing have been devised and adopted by leading technical societies, such as The American Ceramic Society and the American Society of Testing Materials.

As an introduction to our discussion of the properties of the clays of West Tennessee it is necessary to define the terms Ball Clay and Refractory Bond Clay to which we will frequently refer. They are both alike in being clays of high plasticity, they have very considerable strength when dry, and burn dense at 2300° F. or at a lower temperature. The ball clay should burn to a light cream or nearly white color. The bond clay should have even greater strength when dry than the ball clay. Its color when burned is immaterial, but it must be sufficiently refractory to resist fusion at temperatures below 3038° F. Some ball clays are available for use as refractory bond clays. Ball clay is indispensable for the potter and bond clay is indispensable for the maker of graphite crucibles and glass pots.

Among the many important characteristics of clay, there are two of especial interest, namely, its workability or plasticity when tempered with a sufficient amount of water and its conduct when burned. The usefulness of a clay for any specific purpose will depend upon these properties as they exist or may be modified.

PLASTICITY.

Plasticity is that property of a moistened mass of clay which permits the molding into a desired shape. It is a property which is very characteristic of clay but for which thus far we have failed to devise a satisfactory means of measuring. Experienced persons are able to recognize different degrees of plasticity but they are not able to express these different degrees in terms which ar intlligible and satisfactory.

Clay consists of mineral particles of widely varying sizes. Some of these are microscopic and even submicroscopic. These very fine particles less than 0.0002 inch in diameter constitute what is known as the colloidal content, which is regarded as the chief cause of plasticity. The separation of these colloidal bodies would be of interest, but the determination of the quantity would not furnish a measure of plasticity since the property is also dependent upon the amounts of each of many sizes of grains of mineral matter present.

Besides the mineral matter there is present also, especially in these types of clays, a small but probably a very important content of organic matter. It is characteristic of clays which contain lignite particles, or are associated with coal formations, that they are of good or even high plasticity. Not only is organic matter present in this

easily recognizable form but it is possible that the very "fatty" character of some clays may be due to organic matter of an entirely different sort. In fact, differences in plasticity may be due in part to the varying character as well as amounts of organic matter present. The dark color of most ball clay is due to organic matter. The presence of organic matter is not objectionable in the manufacture of most types of wares, since the portion which is not removed in the preparation of the body is destroyed during burning operation.

WATER OF PLASTICITY.

In order to render clay plastic, it is always necessary to add a certain amount of water which will vary with the character of the material. In general, the more plastic the clay the greater the quantity of water that will be required in order to develop the most favorable condition. It is also true that the amount required is not a fixed amount for any clay but varies between maximum and minimum limits. For example, the average variation for a typical American ball clay is 29 per cent for the least amount of water necessary, and 35 per cent the greatest amount of water permissible in developing this property. In general, it is true that the greater the difference in the amounts of water necessary, the greater the plasticity. Some clays show an excessive elasticity which is accompanied by an abnormally high water content. This is quite as objectionable as a low plasticity, since it is commonly accompanied by a loss of strength in drying and burning.

The colloids already referred to as chiefly responsible for the plasticity are in part, at least, glue-like in character and when brought into contact with water take it into its sponge-like structure which swells like gelatin. The granular material constituting the bulk of the clay is coated with this colloidal material. The water which is present in a plastic mass of clay consists of the portion taken up by the colloidal sponge and the portion filling the capillaries between the grains. Since the very plastic clays, such as ball and bond clays, are made up of exceedingly fine grains, the capillary system is very extensive and the amount of water which is present in the plastic mass is very high. In fact the amount of water necessary to develop plasticity may be regarded in a sort as a measure of the degree of plasticity of a clay.

The following table shows the water of plasticity content of some clays:[1]

English Ball clay	44.9% of the weight of dry clay
English Ball clay	40.3% of the weight of dry clay
Tennessee Ball clay	46.1% of the weight of dry clay
Tennessee Ball clay	44.7% of the weight of dry clay
Tennessee Ball clay	37.6% of the weight of dry clay
Kentucky Ball clay	45.2% of the weight of dry clay
Kentucky Ball clay	50.8% of the weight of dry clay
Mississippi Bond clay	31.3% of the weight of dry clay

DRYING AND SHRINKAGE.

The process of drying is the evaporation from the surface of the moisture brought from the interior through the capillaries. The rate of flow will depend upon the temperature and the humidity of the air and upon the structure of the capillary system of the clay. As water is lost, the mineral grains of the clay mass are gradually brought closer together because of the disappearance of the film of moisture separating them.

As the capillaries decrease in size, the movement of the water becomes slower and unequal rates of shrinkage of the center of the mass as compared with the surface may develop, resulting in checking or cracking. When the grains come in contact with each other in the drying process, shrinkage ceases. Some water will still be retained in the voids between the grains. This slowly moves to the surface as the drying continues. The small portion of water in the colloidal sponge is retained very tenaciously and not driven off until the temperature is raised well above the boiling point of water.

If we compare two clays of different degrees of plasticity, we find that the more plastic requires more water to make it workable and that the loss of water in the drying operation takes place more gradually because of the very extensive capillary system. Also we find that there is greater likelihood of cracking and a greater shrinkage.

Excessive drying shrinkage is objectionable in ball clays, since it is apt to be accompanied by a greater tendency to warping and cracking. Further, the plaster molds used in the potteries are made with an allowance for a certain shrinkage. Any variations in the pottery mixtures due to changes in the character of the materials will

[1]Transactions Am. Ceramic Society, XIX, p. 626.

necessitate discarding old molds and replacement with new, which is a costly matter.

The linear drying shrinkages of some typical ball clays are as follows:

Tennessee Ball Clay No. 3, Whitlock, Tenn.	5.5%
Kentucky Ball clay	6.0%
Kentucky Ball clay	7.3%
English Ball clay	5.5 to 6.0%

FINENESS.

Reference has already been made to the varying degrees of fineness of the particles of a clay mass. It is easily possible to separate those of the larger sizes by means of sieves. The smaller particles may be separated by some method of elutriation; that is, the sorting of the particles by means of a gently flowing current of water. By regulating the velocity of flow, these fine grains may be classified into several groups, according to their diameters. The following table[1] shows the results which have been obtained in the examination of some ball clays by this method:

Per Cent of Residue.

	Separated by Sieves. Coarser than 120 mesh	Separated by Elutriation Average Diameter of Particles 0.0577 mm. (0.0022 in.)	0.0354 mm. (0.00139 in.)	0.0167 mm. (0.0006 in.)
Tennessee Ball Clay No. 3	None	0.02	0.24	0.43
Pikes (English) Ball Clay No. 20	None	.....	.....	.....

Smaller than 0.005 mm. (0.000196 in.):	
Tennessee Ball Clay No. 3	99.31
Pikes (English) Ball Clay No. 20	99.00

The exceedingly high percentage content of fine particles is characteristic of very plastic clays, and has a direct relationship to their working properties. The finest portion, that is, those particles having diameters of 0.000196 inch and less, contains the clay suspensoids or colloids which are responsible for the plasticity. The greater part of this fine material consists of granular matter, while the colloids are really only a very small amount. A high content of the so-called clay substance is sometimes accompanied by an excessive degree of plasticity which renders a clay sticky and difficult to work. Other

[1]Bureau of Standards, Technologic Paper No. 1, p. 24.

very important factors in plasticity are the amount, size, relative proportion of sizes, shape and character of the granular material and the amount and character of the soluble salts, *i. e.*, electrolytes present.

Our interest in the fineness of grain of a clay is not limited solely to its relation to the property of plasticity, but extends to other properties, namely, drying conduct, drying shrinkage, warping, tensile or transverse strength and bonding strength.

The processes of drying and shrinkage have already been described. For the reasons which were therein stated, namely, the retention of the water of plasticity in the capillaries and by the spongy collodial material, it becomes evident that the nature and extent of these two factors must have a profound influence upon the drying operation. We may say that the greater the proportion of the fine material the slower the rate of drying, the greater the shrinkage and the greater the tendency to cracking during this stage of the operation. It is the usual practice to mix these clays with coarser materials which overcome these difficulties.

The examination of some standard foreign clays formerly used almost exclusively in this country by crucible manufacturers shows the following content of particles smaller than 0.01 mm. or 0.00039 in diameter.[1]

	Finer Than 0.00039 in Diameter
Gross Almerode clay	61.2%
Klingenberg clay	54.6%
Kaschkau clay	61.3%
St. Loupe clay	86.1%
Breitscheid clay	90.8%

Mere fineness, however, does not determine the relative plasticity of a clay, although there is undoubtedly a close relationship.

TRANSVERSE STRENGTH.

A high degree of plasticity and high strength of the burned clay are usually associated, hence we find the ball and bond clays show high strength tests. This is measured by determining the force required to break a bar of dried clay by supporting it at both ends and applying the load at the center.

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[1]Bureau of Standards, Technologic Paper No. 79, p. 22.

BONDING STRENGTH.

Owing to the tendency of very plastic clays to check and air crack in drying a trial piece may be weakened and give too low a test. To obviate this difficulty and to measure the bonding power of a clay it is the practice to make a mixture of equal parts of clay and sand of a standard size and to test it by the same method as employed for the transverse test.

The following table[1] gives a comparison of some foreign and domestic ball and bond clays:

Modulus of Rupture per Square Inch.

	Without Sand	With Sand
English Ball Clay	376	323
English Ball Clay	366	389
Klingenberg A. T.	345	381
Kentucky Ball Clay	239	234
Kentucky Ball Clay	359	362
Tennessee Ball Clay	187	199
Tennessee Ball Clay	326	228
Tennessee Ball Clay	387	282
Southern Illinois	338	262
Northern Illinois	442	240
Mississippi	645	326

$$\text{Modulus of Rupture} = \frac{3\ Pl}{2\ bd^2}$$

P = weight required to break the piece. l = length of piece between supports. b = breadth of test piece. d = depth of piece.

In general we may state that the ball clays range between 150 and 500 pounds per square inch modulus of rupture. The tensile strength test varies between 125 and 250 pounds per square inch.

The bond clays have been classified by the Bureau of Standards[2] in two groups as follows: Group A, those which show a bonding strength of 325 pounds per square inch or more; and group B, those which have a modulus of rupture between 225 and 325 pounds per square inch.

The practical value of this test is found in the fact that the mixtures used by the potter, crucible and glass pot makers contain from

[1] Transactions of the American Ceramic Society, XIX, p. 626.

[2] Transactions American Ceramic Society, XIX, p. 605.

40 to 70 per cent nonplastic material and a large part of the clay content may be of a sort, for important reasons, which is relatively low in strength. Therefore, it becomes necessary for the user to select the ball or bond clays which will give the maximum strength with the quantity which it is permissible to use.

SLAKING TEST.

This test, which is made as described on a previous page, has been proposed as useful for distinguishing between clays of high and low bonding strength. The strong clays require a longer time for disintegration.

EFFECT OF HEAT.

In considering the changes brought about in a clay by heat, we have the following items of particular interest to consider: The color changes, the shrinkages, the rate of vitrification, the heat range and the fusibility. The relative importance of these varies according to the character and the possible usefulness of the clay.

COLOR.

For the potter, the color of the burned clay is an item of much importance. Other things being equal, he will select for use those clays which, when burned, are the most nearly white in color. Ball clays do not burn white at the temperatures commonly used, but vary in shades of cream. Many of our domestic ball clays from Tennessee and Kentucky are superior to the English in this respect. Color cannot be the only criterion of these clays since their plasticity, etc., are of equally great importance.

Color is not an item of importance in the consideration of the plastic bond clays used in the manufacture of crucibles, glass pots, etc.

PROCESS OF VITRIFICATION.

When clays of any kind are burned, we find that two of the important phenomena are a decrease in the linear and the volume dimensions and an accompanying decrease of the pore space of the material as the temperature is raised providing that we do not pass certain temperature limits. The changes of porosity which the clays pass through are so characteristic and well defined that we may use this

data as a means of classification of clays for different uses, providing that other essential properties are present.

Clays may be roughly classified as refractory and nonrefractory, depending upon whether they fuse or do not fuse at a temperature of about 2,975° F.

The glass pot and crucible clays must be refractory, while the ball clays may or may not be, but both kinds of clay must burn dense, *i. e.*, have little or no porosity at a temperature not higher than 2,300° F.

The practical importance of this lies in the fact that the potter uses ball clay not only for its plasticity and strength but also for the greater strength and denser structure which it imparts to the ware. Density at a low temperature is a necessary property of refractory bond clays, since thereby the wares become more resistant to the corrosive action of glass and molten metal.

An essential difference between domestic and English ball clays is shown in the following table[1] namely, the fact that the English ball clays burn dense or to a low porosity at a lower temperature than the American clays.

Percentage Porosity at Temperature.

	2,010°	2,100°	2,190°	2,300°
English Ball clay	1.99	0.19	0.68	0.5
English Ball clay	3.4	1.28	0.90	0.9
Tennessee Ball clay	27.5	19.1	8.1	0.7
Tennessee Ball clay	22.3	16.4	8.4	2.4
Tennessee Ball clay	20.7	13.9	3.7	2.3
Kentucky Ball clay	19.0	12.7	1.3	1.3

The decrease in porosity which accompanies an increasing temperature is due chiefly to the influence of the fluxes, such as soda, potash, lime, magnesia and iron. These are present in mineral combinations of various sorts which soften as the temperature rises and bind the more refractory particles in a matrix. This softening of the mass results in a gradual closing of the pores, and when the mass has little or no porosity, it is vitrified. The term vitrified, as used, does not mean that the mass becomes glassy.

The rate at which vitrification proceeds may be learned by determining the changes in porosity at various temperatures.

[1]Trans. Am. Cer. Soc., XIX, p. 628.

Fusion occurs when the quantity of softened material becomes so great that the mass is unable to retain its shape and deforms.

Before that stage is reached the clay passes through a distinct period known as over-burning. This is always shown by the development of a vesicular or sponge-like structure which is indicated by a progressive increase of porosity after passing the minimum point as the temperature steadily increases. The most desirable clays are those which maintain the minimum porosity throughout a wide range of temperature. The vesicular structure indicates a softening of the mass which will be accompanied by a bloating and swelling of the clay and its subsequent collapse. Moreover, the development of the vesicular structure will expose the ware made from the clay to the destructive action of glasses or slags which may be in contact with it.

However, such clays as do not overburn too seriously may be successfully used in mixtures with more refractory clays, and, as is commonly the practice, with coarse-grained calcined refractory clay. This coarse refractory material serves as a skeleton which is bonded by the more fusible clay and permits the gases formed by the fusion to escape, thus reducing or preventing a vesicular structure.

SHRINKAGE.

During the progress of burning the clay test pieces decrease in size due to many chemical and physical changes taking place, such as the decrease in porosity, etc. Naturally the shrinkage varies with the temperature.

A typical ball clay from Tennessee shows the following shrinkages:

1,922° F.	2.5%
2,057° F.	6.65%
2,192° F.	9.75%
2,408° F.	13.50%

FUSION OR DEFORMATION POINT.

This is the approximate temperature at which a test piece of a certain size and shape will soften enough to permit the tip of the piece to bend over and touch the base. The rate of heating and the rate at which the deformation take place are important factors. The temperatures are commonly measured by means of pyrometric cones which are widely known as Seger cones. The highest type of fire clay

deforms at cone 35, which corresponds to approximately 3,191° F., and cone 28, or approximately 2,975° F., corresponds to the lowest temperature a clay may deform and be regarded as a good fire clay.

The fusion test is not of importance in the examination of a ball clay for potter's use, but clays which are to be used in the preparation of crucibles, glass pots, etc., should not soften below cone 30 or approximately 3,038° F.[1]

[1]Trans. Am. Cer. Soc., XIX, p. 606.